Bridge Life-Cycle Optimization

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INTRODUCTION

Bridge investment and management decisions are multi-alternative-oriented. Several alternatives might technically be feasible when implementing, for example, a bridge design proposal or a bridge repair strategy. The alternatives may provide the same required function. However, each of them may have different life-cycle cost, environmental impact and anticipated service life. The project presented in this poster is sponsored by the Swedish Transport Administration (Trafikverket) and aims at enhancing the bridge investment and management decisions by Integrating the LCC and LCA with the decision making process. This aim will ensure that the society's needs are optimally met and assist in providing more sustainable bridges.

METHOD:

The research has been started by establishing reliable methodologies for bridge LCC and LCA followed by exploring and clarifying the possible applications of these two methodologies for bridges. The current and future stages of this project are to upgrade and develop the Swedish Bridge and Tunnel System (BaTMan) to accommodate the developed tools. Doing so, automatic input data extraction will be allowed and largest use can be achieved.

CONCLUSION

The project in this poster aims at enhancing the bridge investment and management decisions by upgrading and expanding the use of LCC in the Swedish Bridge and Tunnel Management System (BaTMan). An integrated, cradle-to-grave and comprehensive schema for LCC implementation within the bridge different investment phases was illustrated. A stand-alone computer program (BaTMan-LCC) has been developed for this purpose. The poster presents a unique integrated bridge life-cycle cost approach. This approach integrates all bridge life-cycle issues such as environmental, aesthetical and user cost aspects and makes them measurable and comparable like the bridge initial cost. This approach should represent the platform for the bridge tenders evaluation process in future.

BRIDGE LIFE AND THE POSSIBLE LCC APPLICATIONS

Bridges are vital links in many roadway networks and represent a big capital investment for both governments and taxpayers. They have to be managed in a way that ensures society's needs are optimally met. Many countries are using the bridge management systems (BMSs) as the main tool for the effective management of their bridges. Although many BMSs contain some form of life-cycle costing (LCC), the use of LCC in bridge engineering is scarce. LCC in many BMSs has mainly been applied within the bridge operation phase to support decisions related to existing bridges. LCC has several useful applications within the bridge entire life, from cradle to grave. When more than one alternative is available, LCC can be used to specify the most cost-effective one. FIGURE 1 presents the typical Swedish bridge investment and management phases and simultaneously addresses the possible LCC applications and saving potential.

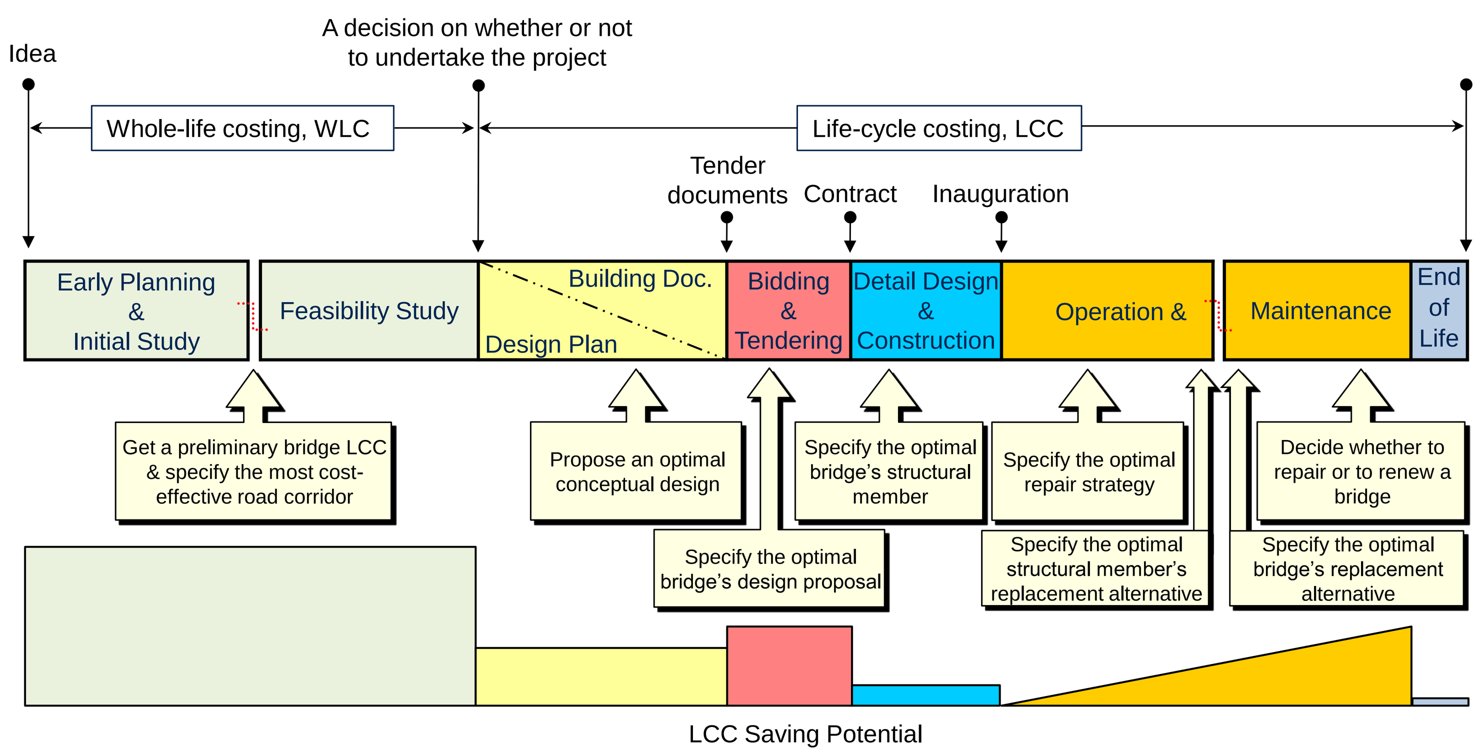


FIGURE 1 Bridge investment phases in Sweden, the possible LCC applications and saving potential

INTEGRATED BRIDGE LIFE CYCLE COST APPROACH FOR EXTENDED BRIDGE SUSTAINABILITY

Currently, LCC is more of a concept than reality in bridge engineering and mainly considers the conventional cost terms. Currently, the concept of the lowest bid is normally used when deciding a contractor. However, the lowest bid conventionally reflects the lowest first cost, not the lowest cost of ownership. In recent years, an expansion of the LCC concept has been made by also taking user costs into account. There are also third-party costs or spill-over costs. These costs are indirect costs which incurred by entities who are neither the bridge owner nor direct bridge user. The bridge life cycle issues and cost categories that included in the new integrated bridge LCC approach are schematically presented in FIGURE 2.

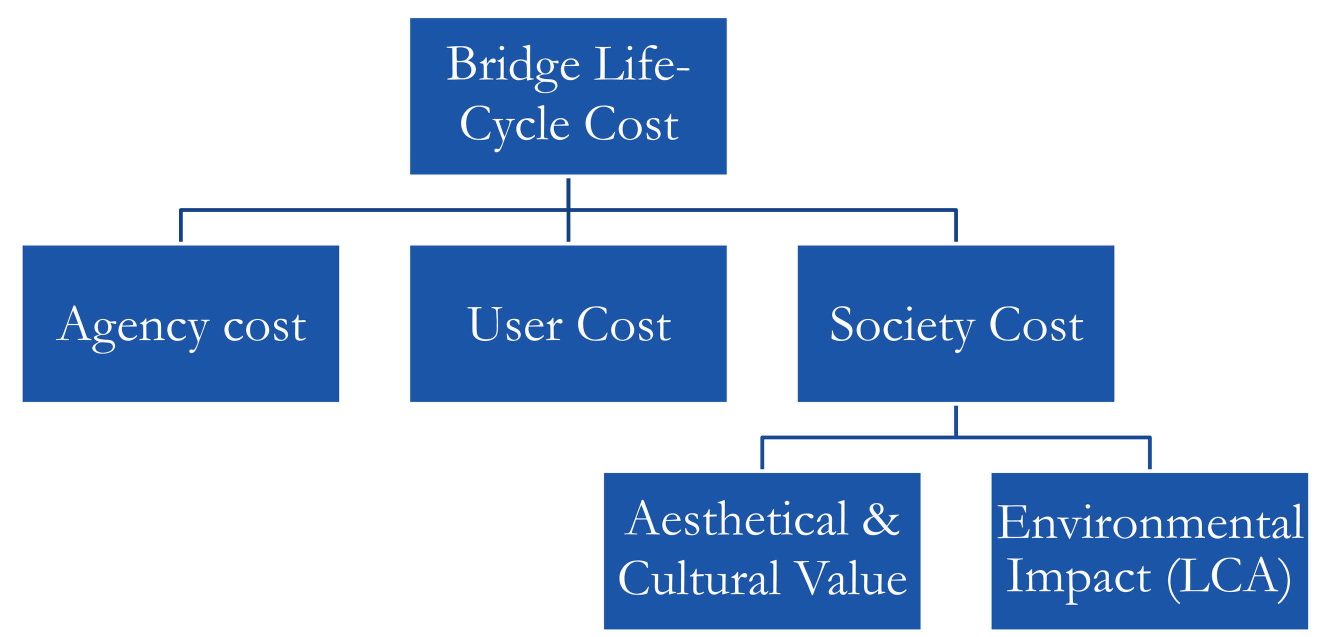


FIGURE 2 bridge investment life cycle issues and cost categories

THE SWEDISH BRIDGE AND TUNNEL MANAGEMENT SYSTEM (BaTMan)

Sweden has a long tradition in bridge management. Since 1944, information about the condition of the national road network has been documented and stored in different archives. The Swedish Transport Administration (Trafikverket) is the largest bridge manager in Sweden. The latest update of Trafikverket's BMS is called a Bridge and Tunnel Management system (BaTMan), which was introduced in 2004. Today, BaTMan is handling the management of 29,736 bridges with a total bridge area of 7,562,070 m^2 and a total bridge length of 658,986 m. All information is given on repair, strengthening, and maintenance, including their costs. BaTMan is a computerized Internet based system, which means that users can always have access to updated information about the actual bridges on-line (https://batman.vv.se/). Furthermore, the system consists of a separate navigation tool (WebHybris) that can access the BaTMan's database and answer any related question for any research or management purposes. BaTMan is recognized as the best-known software-based digital BMS in Europe.

BaTMan-LCC PROGRAM

BaTMan-LCC program is a stand-alone bridge LCC computer program developed by the structural engineering and bridges division at the Royal Institute of Technology. The program consists of many LCC models for the different LCC at the different bridge investment phases. Specially designed work-zone user cost models are integrated within the different applications in this program. The program is using the BaTMan bridge inventory day as the main database for anticipating most of the LCC input data. Considering cost records for 2,508 bridges constructed between 1980 and 2011, the average real initial costs of different bridge types in Sweden are schematically presented in FIGURE 3. FIGURE 4 presents the front page of this program and the included LCC applications. The current and future stages of this project are to upgrade and develop BaTMan to accommodate the BaTMan-LCC program as an integrated tool. Doing so, an automatic input data extraction will be allowed and the largest use can be achieved.

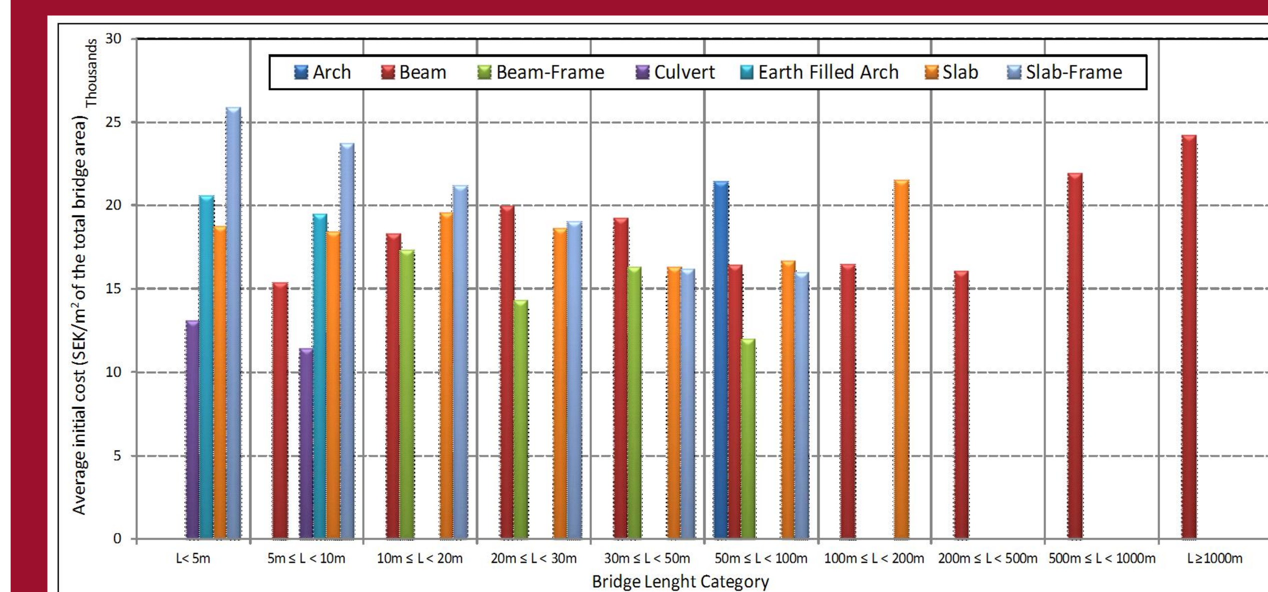


FIGURE 3 The average real initial costs of the Swedish bridges different types

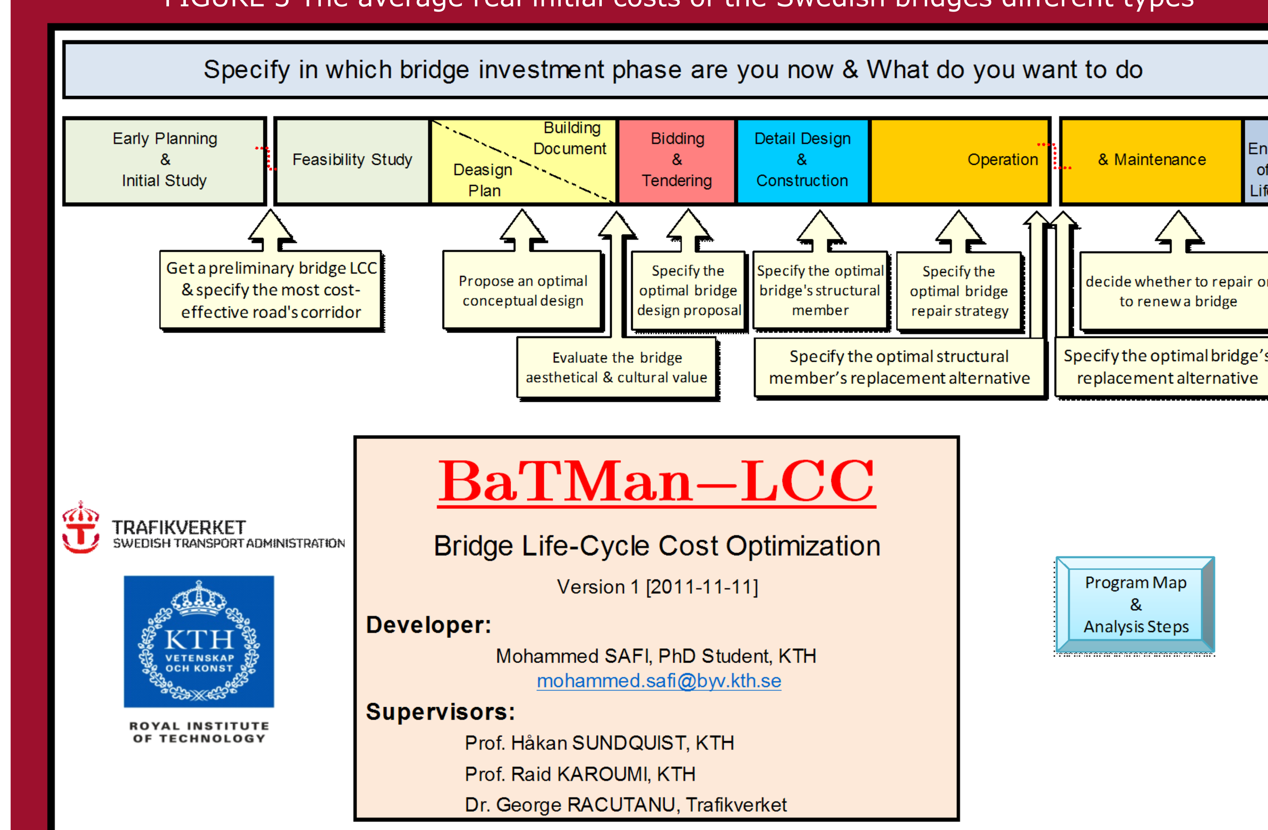
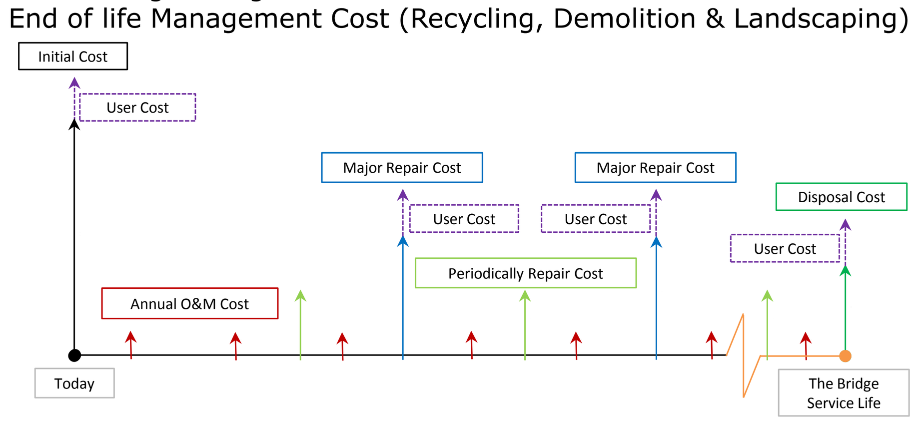


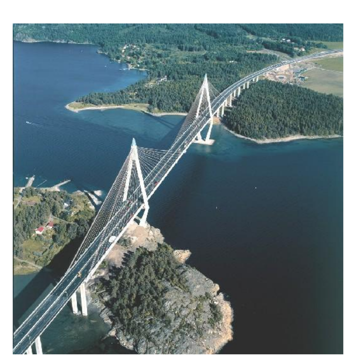
FIGURE 4 The front page of BaTMan-LCC Program

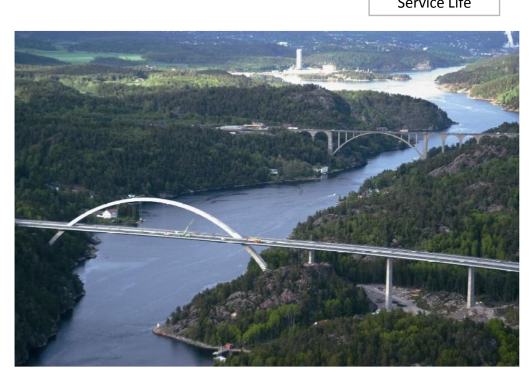
AGENCY COSTS

Agency costs are all costs incurred by the bridge owner over the bridge entire life span. The AG categories sorted in ascending order regarding their occurrence events are shown as follow:

1. Investment Cost
   - Non Elemental Cost
   - Elemental Cost (Purchasing, Construction, & Installation)
2. Life Cycle Remedial Actions Cost
   - Inspection Cost
   - Operation & Maintenance Cost
   - Repair/Rehabilitation & Replacement Cost
   - Strengthening Cost
3. End of life Management Cost (Recycling, Demolition & Landscaping)





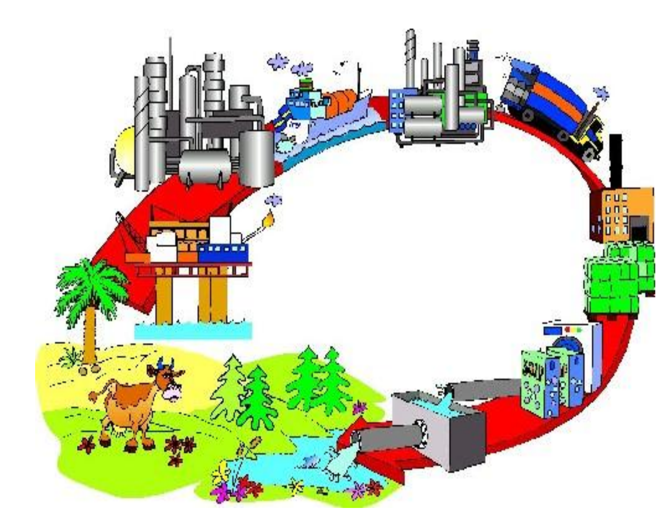


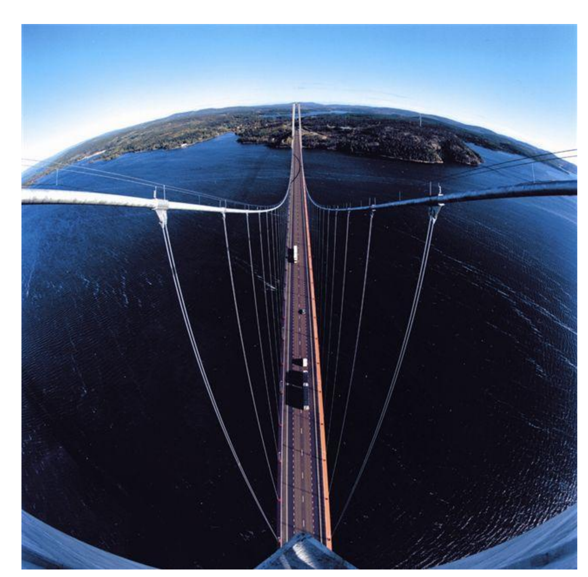
BRIDGE WORK-ZONE USER COSTS

Bridges are public-use property and any roadwork to repair or maintain a bridge might paralyze the entire transport network. The work zone user cost (WZUC) are costs incurred by the users of the bridge as a result of deteriorating conditions of the bridge, such as a narrow width or low load capacity, which result from maintenance, repair and rehabilitation activities, leading to an increase in the vehicle trip time. By including the WZUC in the LCC analysis, the importance of avoiding traffic disruptions will be considered. Consequently, the bridge type that needs fewer repair works during its service life will be indirectly promoted.

BRIDGE ENVIRONMENTAL IMPACT

One issue, brought up in the construction of a new bridge nowadays, is the impact this structure will have on the immediate environment. Beside traditional requirements for the bridge, a trend toward extended attention to the environmental impacts due to different designs, and different maintenance, repair and rehabilitation strategies, are growing stronger. Life-cycle assessment, LCA, is a technique for assessing the potential environmental aspects associated with a product, a product system or an activity.





BRIDGE AESTHETICAL & CULTURAL VALUE

Bridges are often seen more or less as sculptures and icons which the citizens may relate with the soul of the city. Some alternatives have exceeded all cost estimates but they have been chosen as the best. This atmosphere and the will to identify the town and its values with an icon may motivate for bold and spectacular solutions. The inclusion of this value in the evaluation process leads to eliminate the worst aspects of bridge design and encourage the best.

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