BRIDGE MANAGEMENT ANALYTICS FOCUSED ON SUSTAINABILITY AND ECONOMIC GROWTH

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Abstract:

The transportation sector in various countries are facing the daunting challenge of sustainable development. In recent times, bridges on the network are experiencing failure. Sufficient data is available for analysis and comparison between different bridges. Very little data is available on the contribution of the existing bridge towards economic growth over the years. Life cycle cost analysis [LCCA] for bridges is carried out before actual construction to decide on the commercial viability of bridge construction. LCCA also needs to be carried out to reflect the changes in the scenario emerging from dynamic behaviour in bridge structure. This dynamism of the bridge is captured within Global Analytics for Bridge Management [GABM]. GABM is oriented towards fulfilling the objectives of sustainability, the process also ensures economic growth. GABM has maintained the focus on rehabilitation intervention which helps in evaluation of impact on sustainability. Tangible and intangible IRR ensures sustainability is maintained without compromising economic growth.

Keywords: Global Analytics for Bridge Management, Unified Bridge Management System, LCCA, Sustainability.

1 Introduction

The life-cycle cost analysis (LCCA) approach is used to calculate the overall cost of infrastructure ownership. Bridges within the array of infrastructure projects are the focus of this research. LCCA includes all expenditures associated with purchasing, owning, and disposing of a structure or structure system. It is notably beneficial for comparing project options that meet the same performance criteria but differ in terms of initiation and operation expenses; to choose the one that optimizes net savings. The goal of LCCA is to evaluate the total costs of project choices and to select the design that ensures the infrastructure has the lowest overall cost of ownership while maintaining quality and function. [1,2] To reduce life-cycle costs, the LCCA should be performed early during the design process, when there is still time to alter the design (LCC). The first and most challenging task of an LCCA, or any economic evaluation technique, is to assess the economic implications of alternative structure and its system designs and to quantify and describe these impacts in monetary terms. The primary goal of the Bridge Management System [BMS] is to optimize expenditure utilization by maintaining a balance between preserving a sustainable environment and managing the economic benefits of bridge constructions with a longer life length. It should ensure that the sustainability qualities of any bridge project are maintained throughout its life cycle, including maintenance, rehabilitation, restoration, and replacement. [3,4] The application of Life-Cycle Cost Analysis [LCCA] provides sustainability management throughout infrastructure design and maintenance. LCCA is used to analyze the overall financial cost of bridge project choices and to select the design that ensures the bridge has the lowest cost of ownership consistent with its quality and function. If the advantages of Social, Economic, and Environmental aspects of the bridge project are also considered, LCCA becomes more viable. Global Analytics for Bridge Management [GABM] is an analytic tool that enables bridge management teams to achieve the delicate balance between sustainability and economics. This is a major emphasis area for GABM. This guarantees that the bridges have a long-life cycle while remaining cost-effective. [3,4,5]

The study aims to create a full system that employs algorithms to optimize fund allocation, manage life cycle expenditures, and ensure sustainability. The system provides decision-makers with tools for optimizing bridge maintenance plans and repair strategies over time while keeping a budget limit and other constraints in mind, allowing them to determine feasible and practical plans and develop new strategies for managing public infrastructure assets in a way that ensures long-term sustainability while keeping budgets constrained. The analytics module inside the Global Analytics for Bridge Management System [GABM] provides a feasible solution by ensuring bridge infrastructure sustainability without jeopardizing the region's economic growth potential.

2 Sustainability and it's Importance

"Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The sustainability of any infrastructure is of great importance for its long-term integrity and safety. This is also true for bridges. By adopting sustainable practices, bridges can be designed to last longer and be more resilient to extreme weather events and other environmental challenges. To achieve an optimal range of service, operational safety, and maintenance for existing and future users in an economically efficient way and to develop investments in a cost-efficient manner it is critical to adopt the Sustainability process. [11] Sustainability is characterised as preserving the current social, economic, and environmental framework for the current generation while also ensuring that it is preserved for the following one. Any bridge management system's decision-making process should ensure sustainability. GABM facilitates the management of the bridge's life cycle while enabling the application of sustainability. The onus of implementing prompt and timely interventions lies with the users of GABM. This guarantees that bridges will last the entire designed service life.

By decreasing the use of raw materials, such interventions guarantee that the life cycle costs and environmental effects are reduced. By optimising the benefits for the specified costs, these interventions improve environmental and economic management over the full life cycle.

Controlling the cost-effectiveness in the design of such interventions, ensuring a reduction of detour travel time, congestion, and traffic jams delay, which ensures avoiding productivity loss and its impact on the reduction of GDP of the area of influence of the bridge. By reducing or avoiding failure/collapse and increasing network reliability, the such intervention also guarantees increased social benefits.

These factors have an impact on travel safety, fatality rates, and the prompt delivery of goods and raw materials. All of these are essential to maintaining the reliability of the network which ensures a stable GDP. Avoiding traffic bottlenecks and allowing for lengthier travel times due to detours in the event of a prolonged closure of the bridge due to collapse will help the environment by reducing carbon emissions [24,25]. LCCA enables the owners to foresee and plan investments in a very cost-efficient manner, ensuring sustainability. Ensuring the desired level of service to current and future bridge users in the most cost-efficient way. LCCA helps to prioritise investments in the assets that need them the most.

The sustainability objectives are as follows: Reduce virgin material use; Optimize waste stream; Reduce energy use; Reduce emissions to air; Maintain or improve hydrologic regime characteristics; Maintain biodiversity; Enhance community values and sense of place; Improve safety; Improve access and mobility; Improve local economy; Increase lifecycle efficiency; Promote innovation.

The final goals of sustainability are ensured by proper evaluation and implementation as derived from Bridge LCCA. The sustainability analysis provides direction for improving the sustainability of bridge infrastructure projects and the rationale for undertaking specific actions.

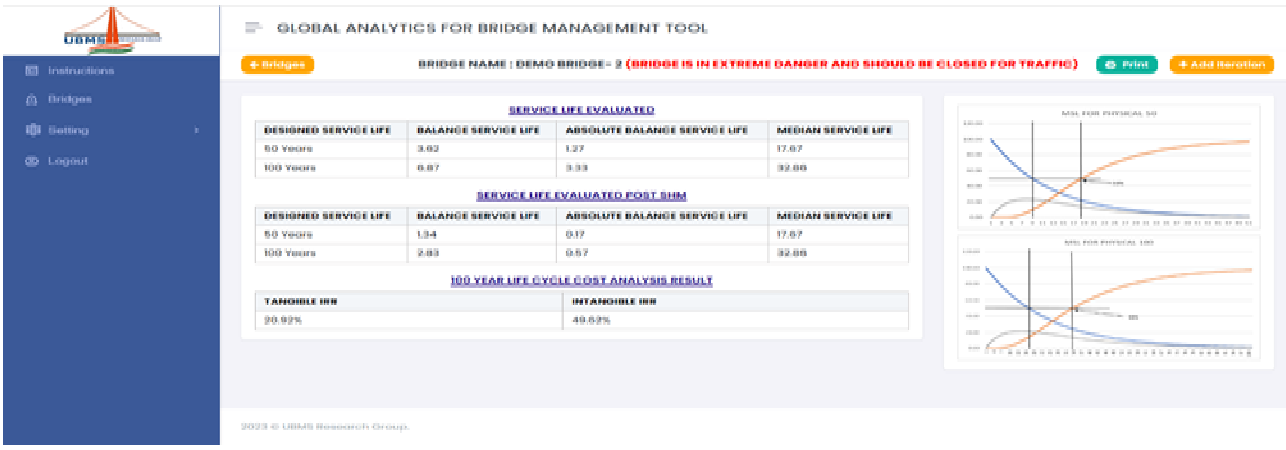


Figure 1. *Result Screen with SHM Sustainability enabled*

3 Factors affecting Sustainability in Bridge Projects.

In the bridge engineering community, sustainability means planning, designing, constructing, and managing bridges that maintain a balance between the three pillars of sustainability: social, economic, and environmental considerations. A bridge constitutes a large investment of natural, material, financial, and human capital and thus has the potential for significant positive and negative effects on the environment and society throughout its long life.
Various factors influence Bridge's Sustainability. The main influence arises from unplanned activities. Planning is the key to maintaining Sustainability. The entire designed service life of the bridge structure requires various types of interventions. Regular Inspection and recording of the bridge status is the starting point.

From the scrutiny of the historical data emerges clarity about the long-term distress affecting the bridge structure. Deterioration modelling is possible once these factors are identified.

From the deterioration model, the best-suited remedial intervention is designed. Alternative designs need to be prepared for the evaluation of cost efficiency. Implementing the most cost-efficient solution is the key to improving sustainability. GABM application empowers the user to attain very high standards of Sustainability.

GABM provides scrutiny of historical narratives. It includes LCCA to enhance cost-efficient solutions. Rigorous implementation of the principles to manage planned levels of materials, resources and precision in selecting alternatives and time to provide intervention are all important. The best results from any remedial intervention are possible in a very small-time window for bridges. The graphical data from the deterioration model provides clarity on this critical aspect to ensure Sustainability.

4 LCCA Analytics:

The implementation of the Life Cycle Cost Study allows for a detailed financial analysis of bridge infrastructure. Vehicle operating expenses, maintenance expenses, and environmental impact expenses are all taken into account. Vehicle Operating Costs (VOC) are important from the perspective of the user; since VOC are reduced when bridge infrastructure delivers upgraded and better operating advantages. The importance of Value of Time is crucial for both passengers and freight shipments since it is a measure of the time saved owing to the presence of the bridge in the network. The benefits of VOC and VOT reductions are immediate (tangible) and are accounted for in standard LCCA. The Life Cycle Cost Study provides for a thorough financial examination of bridge infrastructure. Vehicle running costs, maintenance costs, and environmental impact costs are all taken into account. The immediate tangible advantages of VOC and VOT reductions are accounted for in conventional [standard] LCCA. [7,8,9]

This approach is commonly used to assess the Benefit-Cost ratio of any infrastructure, including bridges. Aside from these obvious costs and advantages, the presence of the bridge has a few hidden or indirect (intangible) consequences. Increased gaseous emissions are a classic example of a negative intangible influence.

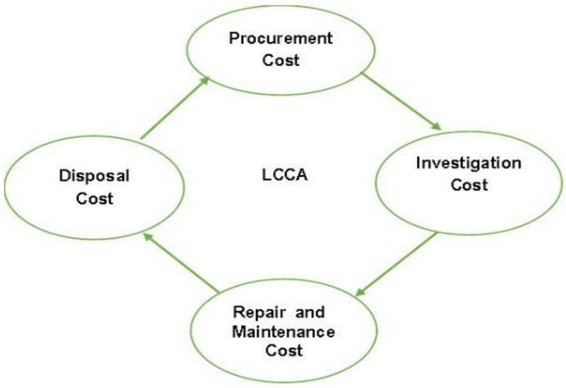


Figure 2. *Life Cycle Cost Analysis Process in GABM*

Few bridges have a significant influence on the environment, forest, or vegetation regions around them. This results in a reduction of the overall benefit arising from the bridge project. On the positive side are the effects which result from increased economic activity between the two communities connected by the bridge. The second positive consequence is related to the increased connection accorded by the bridge and the influence on the social lives of the two communities that utilise it by providing more options to source employment owing to the ease of travel. All these indirect advantages and costs are dynamic and change over the life of the bridge due to the dynamic situation between the two communities over the years. It is impossible to assess and account for such costs and benefits unless regularly updated observations and records are accessible within bridge management to link the dynamics of such changes. The presence of the Socio-Economic parameter inside GABM records the changing scenario of the social and economic elements as a result of the bridge's existence. These records are updated each time an inspection is performed and recorded within GABM. A study of the records and a technical examination of several prior research were used to overcome the difficulty of linking the Socio-Economic parameter to estimate the intangible costs and benefits. Intangible costs and benefits within LCCA calculations, as well as the consequent Internal Rate of Return (IRR) and Benefit-cost ratios, are demonstrated to be more dynamic and realistic in the GABM system. Intrinsic benefits for bridge infrastructure derived from socio-economic considerations are added to the gains. This sort of financial evaluation ensures that rigorous financial due diligence is also integrated into the decision-making process for bridge management. [8,9]

The long-term integrity and safety of bridges rely heavily on their sustainability. Bridges may be constructed to survive longer and be more robust to harsh weather events and other environmental issues by using sustainable methods. Sustainability refers to providing the best possible service, safety, and maintenance to current and future bridge users while being economically viable. [10,11,12] The LCCA is a decision-making tool that is notably useful from the time the bridge is designed until the time it is decommissioned [entire life cycle of the bridge]. Bridge management systems need to focus on bridge maintenance, strengthening, repair, and rehabilitation. This guarantees that bridges last for the entire designed service life without needing to be replaced prematurely. LCCA allows owners to anticipate and plan investments cost-efficiently. It also allows for the cost-efficient maintenance of the bridge during its entire operational life range.

5 LCCA'S Impact on Ranking Process:

LCCA enables owners to anticipate and plan investments cost-efficiently, ensuring sustainability and the delivery of the greatest level of service safely to current and future bridge users. LCCA enables us to prioritise investments on the bridge asset that requires them the most. It also allows for the cost-cutting essential to ensure the bridge's operation for the entire length of its designed service life. A risk-based study is utilised to identify cost-effective expenditures during the conceptualization, design, construction, and entire operational service life of the bridge to ensure optimization. [3,5,8,9]

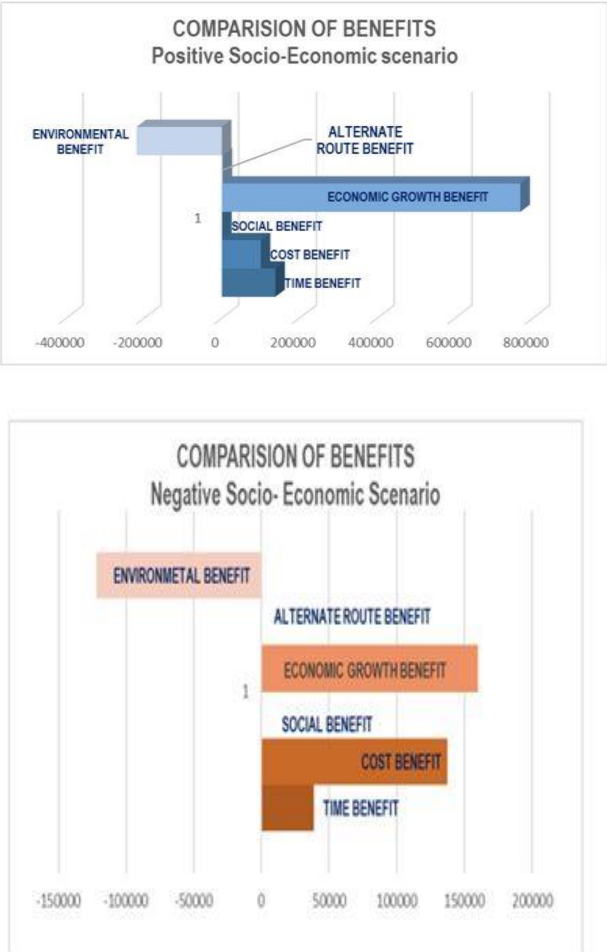
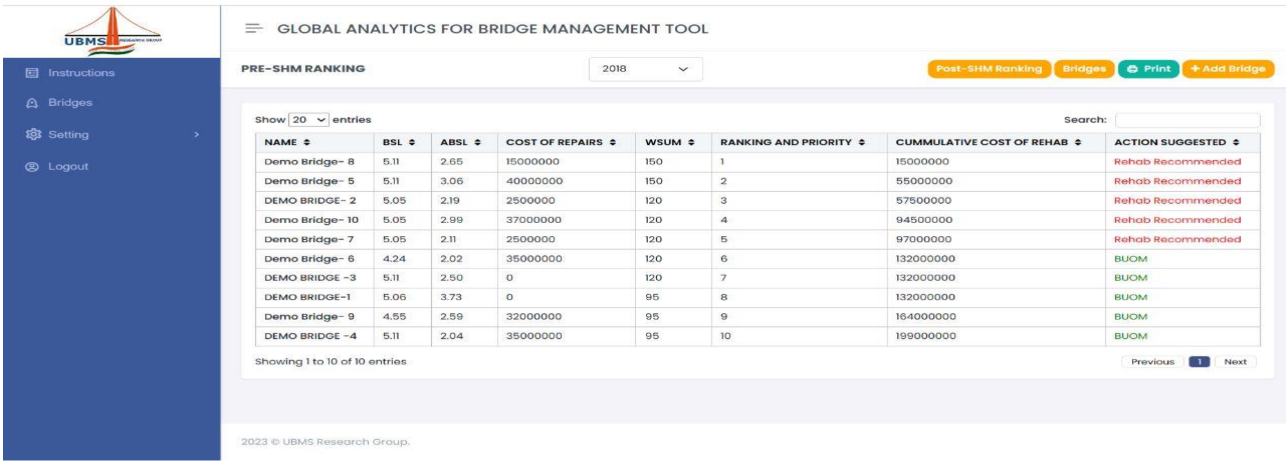


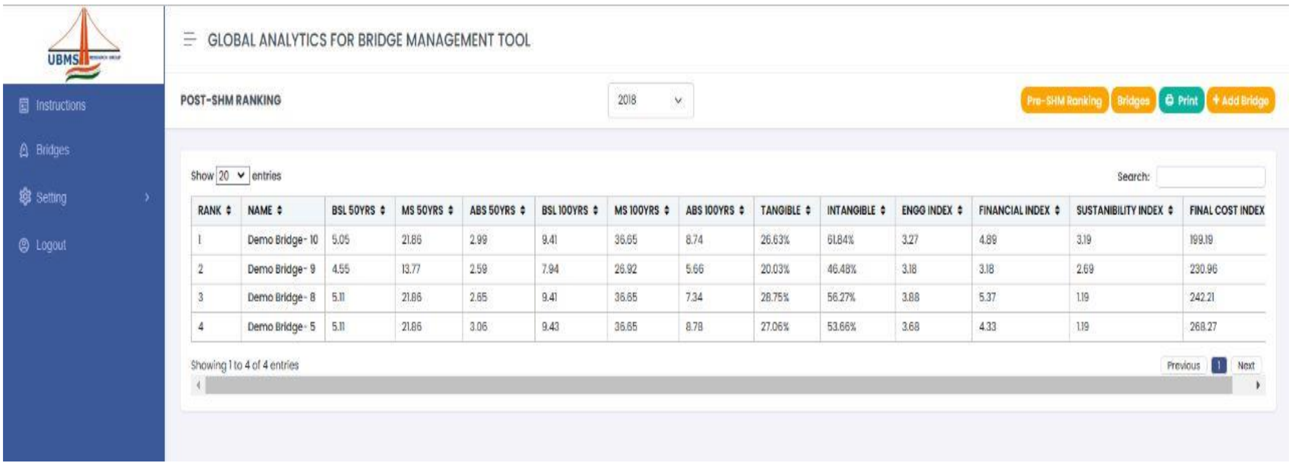
Figure 3. *Comparison of Benefits*

The above chart in Figure 3 shows the impact on the financial calculations due to the positive and negative socio-economic scenarios. The main intangible negative impact arises from the negative impact on the environment in the close vicinity of the bridge due to pollution from emissions due to the increased movement of vehicles. LCCA enables us to avoid the construction of Bridges with high negative impact. The decision-making regime of GABM enables us to govern the investments and achieve optimization of capital allocation, which is essentially the core function of any Bridge Management. The priority and ranking procedure in GABM Analytics determine the priority assigned to a specific bridge among a group of bridges in need of rehabilitation intervention. The influence of LCCA on the ranking process is demonstrated by an actual example of a set of bridges numbered from 1 to 10 for clarity. When LCCA analytics are not used and the ranking is based on a traditional process determined by Wsum, the ranking is different than when the ranking is subjected to analytics using LCCA and the impact of socioeconomic parameters and the importance of the type of road is accounted for in the ranking process. The two tables above show the influence of LCCA on the ranking process.



NAME	BSL	ABSL	COST OF REPAIRS	WSUM	RANKING AND PRIORITY	CUMMULATIVE COST OF REHAB	ACTION SUGGESTED
Demo Bridge- 8	5.11	2.65	15000000	150	1	15000000	Rehab Recommended
Demo Bridge- 5	5.11	3.06	40000000	150	2	55000000	Rehab Recommended
DEMO BRIDGE- 2	5.05	2.19	2500000	120	3	57500000	Rehab Recommended
Demo Bridge- 10	5.05	2.99	37000000	120	4	94500000	Rehab Recommended
Demo Bridge- 7	5.05	2.11	2500000	120	5	97000000	Rehab Recommended
Demo Bridge- 6	4.24	2.02	35000000	120	6	132000000	BUOM
DEMO BRIDGE -3	5.11	2.50	0	120	7	132000000	BUOM
DEMO BRIDGE-1	5.06	3.73	0	95	8	132000000	BUOM
Demo Bridge- 9	4.55	2.59	32000000	95	9	164000000	BUOM
DEMO BRIDGE -4	5.11	2.04	35000000	95	10	199000000	BUOM

Figure 4. *Convention Ranking Process*



RANK	NAME	BSL 50YRS	MS 50YRS	ABS 50YRS	BSL 100YRS	MS 100YRS	ABS 100YRS	TANGIBLE	INTANGIBLE	ENGG INDEX	FINANCIAL INDEX	SUSTANIBILITY INDEX	FINAL COST INDEX
1	Demo Bridge- 10	5.05	21.86	2.99	9.41	36.65	8.74	26.63%	61.84%	3.27	4.89	3.19	199.19
2	Demo Bridge- 9	4.55	13.77	2.59	7.94	26.92	5.66	20.03%	46.48%	3.18	3.18	2.69	230.96
3	Demo Bridge- 8	5.11	21.86	2.65	9.41	36.65	7.34	28.75%	56.27%	3.88	5.37	1.19	242.21
4	Demo Bridge- 5	5.11	21.86	3.06	9.43	36.65	8.78	27.06%	53.66%	3.68	4.33	1.19	268.27

Figure 5. *Modified Ranking Process*

6 Conclusion:

Numerous infrastructures and services are currently facing challenges, including increased annual maintenance expenses, ageing equipment, and the consequences of climate change. The given reliability-based life cycle analysis of the ageing structures model's main purpose is to fulfil the required performance. This must also consider and guarantee the economic, social, and environmental consequences of various maintenance and safety measures. The use of the LCCA tool to study the costs and benefits during the service life then is applied to the decision-making process. Under GABM, data on a variety of socioeconomic aspects are continually updated. The use of this data in LCCA guarantees that a Sustainability emphasis is incorporated into the decision-making process. This strategy also protects sustainability goals. This procedure assures that Bridge meets current needs without jeopardizing future generations' capacity to meet their own. A sustainable Bridge maintains the balance of social, economic, and environmental concerns. We ensure that the different economic and sustainable objectives are met by utilising GABM's Bridge Management Analytics. The main advantage of GABM Bridge Management Analytics is that it can be used in conjunction with any current Bridge Information System/Bridge Management system. Minimum fundamental data record requirements are either accepted from the current BMS or submitted by the user. GABM Analytics provides a comprehensive answer to current challenges in any Bridge Management.

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