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Development of life cycle costing framework for highway bridges in Myanmar

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Abstract

The aim of any engineering design is to minimize the total cost of the structure without compromising the functional requirements while maximizing the utility of the structure to the users in particular and to the society in general. Life cycle costing is a technique for determining the most effective capital investment option for achieving technical-economic optimization of a structure/system. This paper briefly describes a detailed procedure for developing a framework for life cycle costing analysis (LCCA) of highway bridges in Myanmar. The paper discusses various cost components and other statistical factors that need to be taken into consideration while assessing the life cycle cost (LCC) of a highway structure. A stepwise procedure to determine various cost components that come into LCC calculation is also illustrated. The effect of uncertainties associated with various factors on the total cost of the structure is demonstrated performing sensitivity analysis. An attempt is also made to demonstrate how better quality construction with increased initial cost can lead to lower LCC of a highway structure. The study has made a call for the development of comprehensive life cycle costing framework for transportation-related projects in Myanmar in order to be able to strike a balance between the need for maintenance and replacement of highway structures and limited funds available for their upkeep.

Keywords: Life cycle cost; Cost optimization; User cost; Highway structures

1. Introduction

A nation's economic strength is reflected in its infrastructure assets. The capability of any developing country to produce and sustain economic growth is directly related to its ability to transport the goods and services that it produces. A good road network/system is very important to economic activities of a nation as it plays a pivotal role in disbursing basic public services like food distribution, water supply, waste removal, and medical facilities both efficiently and economically. The success of such a system depends on the ability of policy makers to strike a balance between available resources and the need for creation of new facilities and maintenance and repair of existing infrastructure components.

Recent developments in Myanmar have led to a rapid, continuous increase in traffic volumes on both urban and rural roads. The need for renovating old bridges and constructing new ones has consequently increased. According to Public Works Department (PWD) year 2001 database, Myanmar has a road network with more than 34,600 bridges (including culverts) totaling a length of approximately 550 km. The nation still needs an extensive network of highways and bridges to make its infrastructure system more efficient and the Government has been giving special focus on the development of the national road and bridge network to maintain its present growth rate of economy [1]. As these structures approach their designed service life, a plan has to be implemented to repair or rehabilitate them. These repair and rehabilitation operations consume significant part of the limited funds available. The efficient use of these available funds can be achieved by

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optimizing the whole life cost of structures rather than just initial cost of construction only. Therefore, in order to strike a balance between available funds and the need for repair and replacement of these infrastructure components, it is important to develop a comprehensive technical-economic optimization methodology that takes into account lifetime management (inspection, repair, rehabilitation and replacement) costs in addition to initial cost of construction.

The aim of any engineering design is to minimize the total cost of the structure without compromising the functional requirements while maximizing the utility of the structure to its users in particular and to the society in general. The client and designer together play an important role in making the cost effective and environmentally conscious choices in the selection of the design and construction method and materials, which significantly influences both resource consumption and management perspectives, substantially impacting annual operation and maintenance costs. Therefore, infrastructure design should be viewed from life cycle costing perceptive as it has the greatest potential of minimizing a structure's whole life cost during planning and design stage at which changes are most easily implemented and where resistance to change is the least [2].

Life cycle costing is an economic assessment of an item, area, system or facility considering all costs of ownership over an economic life, expressed in terms of equivalent dollars [3]. It takes into account time value of money and reduces a flow of running costs over a period of time to a single current value or present worth (PW). Life cycle costing can be used as a management tool or as a management system [4]. As a management tool it can be used intermittently throughout the economic life of the structure, whenever different options are available, to determine the alternative with the lowest LCC. On the other hand, as a management system in continuous operation it can be used to actively manage the asset throughout its service life. LCCs estimated at one stage are carried through into the budget for the next stage.

Operation and maintenance costs constitute a major portion of the total LCC of a structure [5]. One way to create a more comprehensive view of costs in different phases of a civil engineering project is to perform LCCA. LCCA takes into account all aspects of lifetime cost of the system such as agency costs and the impacts of the system on the users in particular and on the society in general. The main motivation to use LCCA is to increase the possibility of cost reductions during operation and maintenance even if that means spending somewhat more during planning and development [2].

Comprehensive structural optimization requires a lifetime perceptive, that is, the explicit consideration of design, construction, services, inspection, maintenance and decommissioning [6]. Several researchers have developed methodologies for bridge design and management system based on lifetime costs and benefits (e.g. [7–9]). Bridges and roads are important components of infrastructure system without which basic public services cannot be efficiently disbursed. Repairs and maintenance of these components consume a lot of resources. Many researchers and practitioners, for e.g., [10,11], have proposed optimal maintenance strategies for critical bridge elements. Frangopol et al. [12] and Yanev [13] expressed the importance of the need for the application of LCCA method to maintenance planning decisions of the bridges, which are on the brink in the US national highway system. The purpose of this paper is to demonstrate a stepwise procedure for developing a comprehensive framework for LCCA of highway bridges in Myanmar. This paper also aims at encouraging the application of life cycle costing approach to transportation-related projects in Myanmar so that the optimal situation is arrived at more often than not.

2. Methodology

A highway reinforced concrete (RC) bridge, newly constructed using suspended cantilever method, is selected for the study. The reason for selecting this bridge for the study is that, in Myanmar most RC bridges are being constructed using this method. LCC components of highway structures comprise agency costs, user costs, accidents and external cost components. Even though this study attempts to integrate initial cost of construction and other components of LCC in predicting the total cost associated with a bridge over its intended service life, accident costs and external cost components are not included in the LCCA of the Example Bridge due to insufficient statistical data. A good illustration of estimation of these costs can be followed in [14,15].

The authors collected all cost data at different levels of detail from bills of quantities (BoQ) of the Example Bridge, maintenance season average daily traffic (MSADT) volumes on the highway and maintenance history of some of RC bridges in the country. The authors emphasize on the factors such as delay time cost, additional fuel consumption and maintenance costs incurred whenever a vehicle is caught in congestion, as shown in Eq. (1):

$$\text{Road User Cost} = \text{CDT} + \text{CAF} + \text{CAM}, \tag{1}$$

where CDT represents cost of delay time, CAF represents cost of additional fuel consumption and CAM represents cost of additional maintenance of the vehicle. The impacts on LCC of uncertainties associated with input parameters such as discount rate, MSADT and work zone duration are also studied by performing sensitivity analysis. All cost data are normalized to the equivalent US dollars in the year 1999.