Life Cycle Cost Analysis of Pavement using BIM: Review

Parvathy S M1[1*], Sai Niveditha M G[2], Apoorva Krishna[3]

[1]PG Student, Dept. of Civil Engineering, T K M College of Engineering, Kollam,691005, Kerala, India
[2]Assistant Professor, Dept. of Civil Engineering, T K M College of Engineering, Kollam,691005, Kerala, India
[3]Assistant Professor, Dept. of Civil Engineering, T K M College of Engineering, Kollam,691005, Kerala, India
*Corresponding author
doi: https://doi.org/10.21467/proceedings.156.11

ABSTRACT

The methodology of Life Cycle Cost Analysis (LCCA) for road pavements and proposes the integration of Building Information Modeling (BIM) to enhance the analysis process. LCCA involves estimating the total cost of a project by considering initial construction costs, operational expenses, and maintenance costs. To minimize the life cycle cost of pavements, it is crucial to address the original cost alongside the requirements for pavement preventive maintenance. The study highlights the utilization of Economic and Sensitivity Analysis to examine LCCA results using key financial indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR), considering various influential input parameters. By employing software instead of manual estimation, the potential for human error is significantly reduced while saving time. Furthermore, the study emphasizes the growing adoption of BIM in the field of infrastructure and proposes the integration of LCCA within the BIM environment. This integration aims to evaluate different design choices and establish effective maintenance plans. By utilizing BIM tools, a detailed analysis of the pavement's life cycle can be achieved, thereby facilitating the prediction of sustainable pavement solutions through the comparison of alternatives. In conclusion, this work contributes to the advancement of sustainable pavement practices by offering a comprehensive approach that combines LCCA, Economic and Sensitivity Analysis, and BIM. The proposed methodology has the potential to enhance decision-making processes related to road pavement construction, maintenance, and cost-effectiveness, leading to more efficient and sustainable infrastructure development.

Keywords: Life Cycle Cost Analysis, Building Information Modeling

1 Introduction

LCCA, a technique according to the tenets of economic analysis principles, aids in the evaluation of overall project level long-term economic efficiency between competing alternatives of pavement performance investment options and has considerable applications in pavement design and management. The Federal Highway Administration (FHWA) has long pushed for the application of LCCA to all significant investment decisions when such evaluations are likely to boost the efficiency and effectiveness of those choices. In this study, the principal pavement types are examined, including asphalt (flexible), concrete or rigid pavement. The study excludes shoulder design and rehabilitation/maintenance because it concentrates on major elements. The actual proposal of a sustainable design approach for infrastructure is that the decision-making criteria are based on BIM data for projecting a sustainability rating system. Infrastructures can use Building Information Modeling (BIM) to integrate the assessment of maintenance and waste management strategies. that are reusing the usable material like RAP, minimizing costs, the use of raw materials, and future pavement performance design prediction.

Proceedings DOI: 10.21467/proceedings.156; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-961472-7-3

2 Literature Review

The study was focused on the LCCA in Pavement Design. Extensive search and review of published works of literature on the LCCA in pavement design and its corresponding concepts of risk, pavement performance, cost estimation, etc.

2.1 Data Collection

For analysis of LCCA, we need certain input data are needed they are designed analysis period in terms of years, road geometry, performance, cost of each activity, inflation rate, discount rate, construction work zone inputs, agency cost, and user cost. In the study conducted by Yaning Qiao *et al.* [1] the input data chosen were climatic conditions of 24 locations. Climatic factors like temperature variation at different locations, rainfall, wind speed, groundwater presence, and freeze-thaw cycle are considered. General guidelines followed for the analysis were based on AASHTO. In a study conducted by Cristina Oreto *et al.* [2] about the integration of LCCA with BIM, the analysis was done based on the creation of a customized asphalt mixture design layer based on previous experimental studies. Created a set of libraries on BIM having different pavement designs. MEPDG guidelines are widely adopted by road engineers, and integration of MEPDG with climatic data is one method for the data collection and analysis [3]. The impact of flexible pavement on climatic conditions is predicted from the study.

2.2 Pavement Performance

An effective pavement includes improved pavement performance, riding quality, travel safety comfort, and service life [10]. The pavement performance indicators are rutting, roughness, fatigue, cracking, etc. According to the study done by Yaning Qiao *et al.* [1] says that pavement performance was mostly affected by traffic. Traffic data like AADT, truck percentage, pavement structure, pavement material, etc are considered. Fwa *et al.* [4] analyzed pavement performance based on the cost quantification approaches. In the first approach factors, compare were Pavement Serviceability Index (PSI)-Equivalent Single Axle Load (ESAL), and the second approach is based on the user benefits point of view having PSI, ESAL, traffic volume, and time.

2.3 Pavement Modelling

Using the Pavement ME tool, the pavement maintenance decision period was analyzed [1]. From that, a model was developed called the Responsive Maintenance Decision-Making Model (RMDMM). Based on the AASHTO three maintenance activities are chosen overlay, crack sealing, and filling. BISAR tool was adopted to calculate the pavement stress and strain at the bottom of the base period of analysis [2]. The pavement structure was designed based on the M-E analysis in the study conducted by Venkata Mandapaka *et al.* [5] to satisfy the input condition considered.

2.4 BIM Software

BIM technology, a recent and highly promising development in the AEC industry, enables the precise digital construction of an accurate virtual model of a building [11]-[12]. Civil 3D software was widely adopted in road infrastructure. Civil 3D was mainly chosen for use to create the digital terrain model, the vertical and horizontal alignment. By the integration of GIS point cloud data with the Civil 3D by using the triangular irregular method the digital terrain model can be traced out with high accuracy. By using this technology, the real environmental context can be created in the BIM platform, Italy adopted technic and redesign an exciting road to a new one [6]. Revit is widely used by the AEC industry. LCA add-in helps to direct estimation projects with the BIM. Non-experts can use Dynamo software for creating the visual scripts of the LCCA-integrated environment [2]. There are several studies happening about the interdisciplinary BIM-

Proceedings DOI: 10.21467/proceedings.156
ISBN: 978-81-961472-7-3

Series: AIJR Proceedings
ISSN: 2582-3922

based field. Jingxiao Zhang *et al.* [7] suggested the scope of BIM interdisciplinary highway engineering and service areas.

2.5 Economic Indicators

Several economic indicators are mentioned in the published literature. Common indicators are Net Present Value (NPV), Equivalent Uniform Annual Cost (EUAC), Internal Rate of Returns (IRR). Yuanyuan Pan *et al.* [8] use the benefit-cost ratio method to find out the cost-effectiveness evaluation between the alternatives. The Internal Rate of Returns are the best method among all, even though Net Present Value methods are mostly used. Yaning Qiao *et al.* [1] adopted the Net present value (NPV) method as a criterion to calculate and contrast the climatic impacts on pavement's historical and future LCC incurred throughout various life cycle phases.

2.6 LCCA Analysis

Yaning Qiao *et al.* [1] study on the NPV economic indicator was chosen for the analysis. In agency cost, the construction cost, maintenance cost, transportation cost, and EOL cost are considered. Venkata Mandapaka *et al.* [5] considered EUAC as the economic indicator for the LCCA Real cost software was used. The Real cost was based on the AASHTO and FHWA. LCCA can be done in BIM technology using Revit, Dynamo, and LCC add-ins developed by Autodesk tool Add-ins [9]. By using the Autodesk add-ins, the LCCA of commercial building costs is analyzed. The LCCA cost evaluation is done based on agency cost and user cost. Most of the study was based on agency cost [2] and aim to minimize the cost of the road's life cycle to manage the pavement to keep it in optimum condition.

3 Conclusions

As the review was conducted on the Life cycle cost analysis of pavement at various locations corresponding climatic conditions and traffic data were considered. Usually, the agencies design the pavement up to its design period or service life up to 15 years for flexible pavement and 30 years for rigid pavement. The relevance of the LCCA study makes to improve the planning process to adopt the effective design at optimum cost. The study shows the relevance of LCCA procedures in pavement design to manage the highway design according to the increase in traffic conditions and to forecast prediction models to avoid uncertainty funding in terms of pavement maintenance. LCCA has to be studied in Indian condition too because for better understanding.

In this regard, LCCA, and the economic analysis technique, is valuable since it allows for the comparison of the overall long-term economic effectiveness of vying for alternative investments, and thus has crucial applications in pavement design and management. Because of its ability to compile useful information for calculating life cycle cost or performing energy analysis, BIM is a good fit for sustainability. The developed BIM technology application promotes efficiency for the analysis of complex and useful maintenance planning time. The BIM tool allows the designer to choose the best alternatives during the design phase. Helps to bring an effective cost-saving solution with respect to quality and safety criteria incorporated. Integrating the LCCA with BIM technology generated the model which was an exact model with having real environmental context. Through which sustainable pavement can also be traced.

4 Future Study

The Life Cycle Cost Analysis of pavement can be calculated using Real Cost software. By the integration of LCCA with the BIM application Dynamo add-ins of Civil 3D and Revit can also be calculated. For the evaluation of LCCA and LCA of a building, the Revit software is used mainly in which consists of the designing part and the analysis part. We can do the LCCA of pavement in Revit also. Mostly the pavement

design and analysis are done in Civil 3D but the disadvantage of the BIM is that not that developed in the field of transportation. Dynamo run based on the python language, which is slightly difficult.

5 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Parvathy *et al.* (2023). Life Cycle Cost Analysis of Pavement using BIM: Review. *AIJR Proceedings*, 79-82. https://doi.org/10.21467/proceedings.156.11

References

[1] Y. Qiao, Y. Guo, A. M. K. Stoner, and J. Santos, "Impacts of future climate change on flexible road pavement economics: A life cycle costs analysis of 24 case studies across the United States," *Sustain Cities Soc*, vol. 80, p. 103773, May 2022, doi: 10.1016/J.SCS.2022.103773.

[2] C. Oreto, S. A. Biancardo, R. Veropalumbo, N. Viscione, F. Russo, and G. Dell'acqua, "BIM–LCCA Integration for Road Pavement Maintenance," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2676, no. 6, pp. 259–273, Feb. 2022, doi: 10.1177/03611981221074368.

[3] O. Maadani, M. Shafiee, and I. Egorov, "Climate Change Challenges for Flexible Pavement in Canada: An Overview," *Journal of Cold Regions Engineering*, vol. 35, no. 4, p. 03121002, Dec. 2021, doi: 10.1061/(ASCE)CR.1943-5495.0000262.

[4] T. F. Fwa and K. C. Sinha, "Pavement Performance and LifeCycle Cost Analysis," *J Transp Eng*, vol. 117, no. 1, pp. 33–46, Jan. 1991, doi: 10.1061/(ASCE)0733-947X(1991)117:1(33).

[5] V. Mandapaka, I. Basheer, K. Sahasi, P. Ullidtz, J. T. Harvey, and N. Sivaneswaran, "Mechanistic-Empirical and Life-Cycle Cost Analysis for Optimizing Flexible Pavement Maintenance and Rehabilitation," *J Transp Eng*, vol. 138, no. 5, pp. 625–633, May 2012, doi: 10.1061/(ASCE)TE.1943-5436.0000367.

[6] V. Vignali, E. M. Acerra, C. Lantieri, F. Di Vincenzo, G. Piacentini, and S. Pancaldi, "Building information Modelling (BIM) application for an existing road infrastructure," *Autom Constr*, vol. 128, p. 103752, Aug. 2021, doi: 10.1016/J.AUTCON.2021.103752.

[7] J. Zhang, C. Zhao, H. Li, H. Huijser, and M. Skitmore, "Exploring an Interdisciplinary BIM-Based Joint Capstone Course in Highway Engineering," *Journal of Civil Engineering Education*, vol. 146, no. 3, p. 05020004, Apr. 2020, doi: 10.1061/(ASCE)EI.2643-9115.0000017.

[8] Y. Pan, Y. Shang, G. Liu, Y. Xie, C. Zhang, and Y. Zhao, "Cost-effectiveness evaluation of pavement maintenance treatments using multiple regression and life-cycle cost analysis," *Constr Build Mater*, vol. 292, p. 123461, Jul. 2021, doi: 10.1016/J.CONBUILDMAT.2021.123461.

[9] M. Rad, F. Jalaei, A. Golpour, S. Varzande, G. Guest," BIM-based approach to conduct Life Cycle Cost Analysis of resilient buildings at the conceptual stage," *Automation in Construction* 123 (2021) p. 103480, doi: 10.1016/j.autcon.2020.103480.

[10] X. Yang, Z.P. You, J.E. Hiller, M.R. Mohd Hasan, A. Diab, S. Luo, "Sensitivity of rigid pavement performance predictions to individual climate variables using pavement ME design," *J. Transport. Eng. B Pave.* 146 (3) (2020), 04020028, doi: 10.1061/JPEODX.0000182.

[11] S. Azhar "Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry," *Leader. Manag. Eng.* 11 (2011) 241–252

[12] Kavitha B, Molykutty M v. "Life cycle energy analysis of a glazed commercial building using building information modelling (BIM) tools." *Materials Today: Proceedings*2021; 37:940–6, doi: 10.1016/J.MATPR.2020.06.148.