An Integrated Feasibility Management, LCCA, and ANN Framework for Sustainable Highway Construction Zone Maintenance

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Abstract

The construction zones on the highways require a balanced situation that is inclusive of feasibility, safety, environmental accountability and long term efficiency in the maintenance. The current research creates a united approach of feasibility management within highway construction areas through the synthesis of case-based evaluation, life cycle cost analysis and the use of Artificial Neural Networks to predict future maintenance assistance. The research assesses the existing feasibility management as well as evaluates the environmental and safety implication and studies the maintenance strategies that are meant to enhance long-term infrastructure sustainability. The analytical stage involves two highway contexts which include the section of the Aurangabad Highway to Kolwadi Road and the Mumbai-Pune Expressway section. The rigorous and flexible pavements are evaluated comparatively over 30 years with a discount rate of 12 percent and 5 percent inflation rate. The results demonstrate that rigid pavement is more expensive in its initial construction but becomes cost-effective in the long run due to the reduced maintenance needs, and the break-even point is reached in 2029. In one instance, rigid pavement will be 10.39% less expensive than in another, 2048. ANN component will be implemented in MATLAB as a backpropagation feed-forward network with the TRAINLM, LEARNGDM, Mean Squared Error, and 10 neurons in the first layer to help in the future prediction of maintenance cost. The research comes up with a conclusion that a comprehensive approach to sustainable highway maintenance planning includes feasibility assessment, lifecycle economics, safety considerations, and predictive analytics.

Keywords: *Feasibility Management, Life Cycle Cost Analysis, Artificial Neural Network, Highway Maintenance, Sustainable Infrastructure*

1. INTRODUCTION

The highways infrastructure is the cornerstone of the region connectivity, economic interaction, movement, social access, and emergency actions[1]. Highways serve to link rural and urban areas, enhance access to services, business operation, and enhance national and regional transportation networks. Due to this central positioning, highways planning, construction and maintenance are not just engineering projects but long-term strategic activities of infrastructure such as highways that have long-term economic and social impacts[2]. Highway construction zones are unique environments since they are dynamic environments in which construction activity, detours, altering traffic patterns, and operational uncertainty coexist. In this case, it is critical to have feasibility management where projects are viable, cost effective, safe, and sustainable. Maintenance also plays an important role since a highway can not be evaluated based on the quality of its initial completion, but rather on the value that is realized over the long-term based on the effectiveness in which it continues to serve the road users, how safely it can serve the road users and the efficiency with which interventions are handled in the future[3]. This establishes the direct correlation between feasibility control and maintenance plan in highway construction areas.

Fig 1. Road Grading construction

Highway projects are also very complex which is another reason to adopt an integrated management approach. Highway projects will be associated with engineering design issues, environmental effects, land acquisition, coordination among stakeholders, traffic control, funding constraints, regulatory issues, and integration of technology. All these are the factors that affect the viability of a project when being constructed and when it is in operation. Economic feasibility should consider the construction and maintenance costs with time; technical feasibility should consider the suitability of the methods, materials and structural systems; environmental feasibility should take into consideration the ecological effects and the compliances issues; and operational feasibility should ensure that continuity of traffic and safety of the users are not compromised during the implementation process. There is also the need to conduct the risk analysis since the weather conditions, geological conditions, uncertainties of the site, and hazards associated with the construction process can impact the project results. Also, there is a necessity of stakeholder alignment because the local communities, businesses, agencies, and road users all directly feel the impact of the construction zones of highways. As such, a highway project cannot just be carried out physically; it needs to have a coordinated structure that has the capacity to connect cost, safety, sustainability and maintainability in a single decision structure.

Highway infrastructure understanding and management has also evolved due to the technological advancements. The study notes various technological advances that affect the contemporary transportation systems, such as Intelligent Transportation Systems, sophisticated traffic control systems, connected and self-driving cars, Building Information Modelling, drones to inspect the equipment, AR to maintain the equipment, environmental monitoring systems, digital twins, and other innovative materials that ensure safety and durability[4]. The progress in these areas indicates that management of highways is shifting towards more intelligent and data-driven and proactive models. This is more applicable in maintenance planning where predictive techniques can help minimize uncertainty and enhance resource allocation. In this regard, Artificial Neural Networks can be valuable since they can be used as forecasting tools that will help in estimating the future maintenance costs. The current paper integrates ANN with the feasibility management and lifecycle cost analysis and hence acknowledges the fact that long-term infrastructure decision-making should not be based on descriptive or fixed evaluation. Rather, sustainable highway management is increasingly relying on the integration of engineering judgment and predictive and economic analysis.

Fig 2 Highway infrastructures

The picture above Figure 1.2 depicts a construction area on a highway having several lanes and traffic moving on both directions. Barriers and traffic cones are used to guarantee safety through directing traffic and safeguarding work force. Directional signs help one to move around and the construction machinery shows that the road is being maintained or upgraded to enhance the capacity and safety. The last pillars that warrant the current study are safety and sustainability. The development of highways should not only promote environmental friendly activities but also safeguard the workers, commuters and the communities around the highway. Protective road structure, emergency management, correct traffic regulation, street lights, green capitals, eco-friendly products, waste management, integration of renewable energy, climate adaptability, and community involvement are all termed as critical elements of the triumphant highway design. However, the research also creates an understanding that current practices of managing feasibility do not comprehensively tackle these problems in a holistic manner. This leads to inefficiencies and dangers in construction areas and undermining long-term maintenance planning. The study addresses this issue in the analytical chapters which discuss rigid and flexible pavements using the life cycle cost analysis and maintenance forecasting. In the case of the Aurangabad Highway- Kolwadi Road segment, ANN input was made with 20 years of maintenance costs data, and lifecycle comparison under 30 years of concession period was done on both rigid and flexible pavement. The second case scenario that the Mumbai-Pune Expressway is a part of expands the discussion to a significant project of 94.5 km, 6 lanes and a project cost amounting to Rs 16.3 billion. The study will combine feasibility assessment, maintenance strategy, lifecycle cost evaluation, and predictive analytics to create a practical and sustainable framework that will be used to manage highway construction zones.

2. LITERATURE REVIEW

Sepehr Sabeti et al. (2021) investigated the use of AI-based augmented reality to enhance safety at highway work zone and demonstrated that edge AI, wireless communications, and augmented interfaces can enhance the level of worker awareness and exposure to risks, with initial results indicating 24.83 FPS, 48.7% mAP, and an average delay of 5.1 ms over a 120 m[5]. Gaoru Zhu et al. (2020) attempted to simulate the highway feasibility in environmentally sensitive regions using magic cube model based on construction necessity and ecological friendliness with 17 construction-need indices and 9 ecological indices with weighting factor of AHP to come up with feasibility scores[6]. Ahmed Jalil Al-Bayati (2022) was concentrated on injuries and fatalities in highways work zones and emphasized the significance of Internal Traffic Control Plans, which suggests the higher intensity of the safety regulation and better temporary traffic control systems[7]. Yuanyuan Liu et al. (2022) examined the work zone management impact on user carbon dioxide emission in highway pavement maintenance and established that 29.4% of total life cycle carbon dioxide emission is influenced by traffic delays and that work-zone carbon dioxide emission is 51.8% as a result of preventive maintenance[8]. Pratiksha R. Patil (2020) assessed the financial viability of the proposed improvement of the MumbaiPune stretch of NH-4 using HDM-4 model, and observed that the improvement options were economically viable within the 20 years analysis period[9]. Gulnara A. Gareeva et al. (2020) examined the technical and economic planning of road construction with the use of financial information system and found the efficiency of the processing to be improved, the annual economic benefit is 2237.03 rubles, the cost of the software development is 25715.40 rubles, and the payback period is 11 months with a discount[10]. Fei Shan (2021) explored rural highway construction management and maintenance with the focus on activity-based costing, focusing on the labor, material, and indirect cost analysis and the necessity to enhance the local maintenance systems to achieve long-term roadway performance[11]. A combination of these studies indicates that contemporary research in highways is becoming more and more linked to the following factors safety, environmental control, management systems, and cost effectiveness, although not on a single integrated planning model[12].

Nindyo Cahyo Kresnanto (2024) used multi-criteria analysis to the road handling priorities and showed how technical indicators like traffic conditions, stability, degree of saturation, travel speed, and travel time may be integrated with economic indicators like vehicle operating cost, time value, BCR, and NPV to enhance the maintenance priorities[13]. Anna Kharchenko et al. (2022) examined time, cost, and quality relationship in maintenance of roads based on the concept of the silver triangle and suggested a model that would enhance efficiency of the project planning by optimizing these interconnected aspects[14]. Gugilla Aruna (2025) proposed a composite management model of highway maintenance and traffic with optimization and case simulations that demonstrated that work zone planning and diversions could lower the total costs of agencies and users, as well as enhance safety and productivity[15]. The article by Saleh M. Alsultan (2022) has examined risks on health and safety in road work zones in temporary settings in Saudi Arabia and revealed that the risk of crashes was commonly of concern, and driver behavior was reported as the strongest contributor to the risk, and the safety violations were perceived to need stern compliance[16]. Zokaei Ashtiani (2024) made a comparison between green and conventional roads and noted that the lifecycle benefits of green roads such as 16.36% budget saving, zero maintenance in the first 10 years, 26.50% savings on routine maintenance, and 11.80% savings on major repair expenses were realized[17]. Jingyu Li (2022) overviewed widespread issues and maintenance management in highway bridges using field observations, previous methods, and professional analysis, and found out that the maintenance solutions need to be put into context based on local codes, materials, and budget constraints[18]. Qingguo Chang (2023) discussed the optimization of maintenance of highway tunnel electromechanical facilities and justified the proactive and refined management with the help of such advanced monitoring and predicting methods to enhance the reliability and safety of the operation[19]. Taken together, these works support the point that the long-term highway performance is based on the joint control of safety, maintenance, cost and environmental conditions, but also point at the fact that the integrated framework in terms of integration of feasibility management, lifecycle cost analysis, and predictive maintenance is not sufficiently developed[20].

3. Research Gap

Despite the fact that earlier research has been undertaken in exploring the highway work zone safety, environmental management, maintenance planning, traffic efficiency, cost optimization, and economic feasibility, the existing literature is not complete. Most studies examine technical, environmental, and economic factors of highway development in isolation yet few studies have incorporated all the three dimensions into a single decision-support framework to manage overall feasibility. Studies of AI and AR demonstrate great potential to enhance safety in work areas, but the extensive use of such technologies in diverse geographical and economical conditions is a poorly studied field. Similarly, congestion and carbon emissions in the work zone tend to be addressed as independent of a lifecycle maintenance plan, which constrains their applicability in long-term infrastructure strategy. The other critical area of gap is the marginal incorporation of predictive maintenance in lifecycle economics and pavement decision-making on sustainability. These deficits warrant the current research which integrates the study of feasibility management, maintenance plan, life cycle cost analysis, safety and environmental concerns and ANN-assisted future cost forecasting into a single research platform.

3. OBJECTIVES OF THE STUDY

The objectives of the study are:

1. To evaluate current feasibility management practices.
2. To assess environmental and safety implications in highway construction zone.
3. To develop a framework for feasibility management.
4. To analyze maintenance strategies for long-term sustainability.

Problem Statement

The highway construction zones are crucial in the infrastructure development but pose significant problems concerning the safety, environmental effects, and maintenance. Current practices of managing feasibility are insufficiently concerned with these interrelated issues that cause inefficiencies, worker and road user risks, and sustainability problems. As the demand grows to construct a more desirable infrastructure, there is need to revise the current practices in feasibility, evaluate the environmental and safety effects, and establish a more holistic framework that can facilitate successful maintenance and sustainability of the infrastructure in the long-run.

4. METHODOLOGY

The methodology takes a systematic order which is constructed based on feasibility management and maintenance in the areas of highway constructions. This is achieved by starting with reviewing of the relevant books, reports and research sources to be familiar with the key issues relating to highway construction zone management and maintenance. On the basis of this review, a problem statement is constructed and a case study method is embraced. The heart of the analysis is the life cycle cost analysis of road construction options and then analysis results are to be interpreted to come up with conclusions to be used in the effective management of feasibility and maintenance strategies. The research proceeds then in a sequence of topic selection and literature review into case study selection, lifecycle cost analysis, results and conclusion.

1. Research Approach

The research uses a case-based analytical study to evaluate the viability and maintenance practices of highway construction areas. This research combines a feasibility study, including maintenance evaluation, Life Cycle Cost Analysis (LCCA), and an Artificial Neural Network (ANN)-based predictive model, into one framework. The goal of this research is to evaluate both the economic and operational side of highway infrastructure by integrating actual case data with analytical models. This method allows the study to go beyond theoretical discussions and provide an accurate view of long-term pavement performance and maintenance planning.

2. Research Design

The study has systematic and organized design which is initiated by the choice of topics and identification of the problem, proceeded by literature search, selection of the case studies, data collection, and analytical evaluation. The design has made it such that every section of the research is based on the previous one in a logical way, which makes it possible to combine the theoretical knowledge with the practical case study. The research design will also entail the formulation of objectives, identification of relevant variables and formulation of analytical models including LCCA and ANN. Such a systematic organization is useful in providing clarity, uniformity, and dependability of the research results.

3. Case Study Selection

The study utilizes two examples of highways, the Aurangabad Highway to Kolwadi Road and the Mumbai-Pune Expressway. Both case studies show what actually happens when building and maintaining a highway, providing solid data on both cost and performance. The Highway from Aurangabad to Kolwadi will be used for an in-depth life cycle and ANN analysis, while the Mumbai-Pune Expressway will be used to see how big picture infrastructure components affect overall performance. The Mumbai-Pune Expressway is about 94.5 km long and has six lanes, and it costs Rs 16.3 billion to construct; therefore, it is an important benchmark to use in large highway evaluations.

4. Data Collection

The study information is gathered through the secondary and primary sources. The data of maintenance cost is taken over a 20-year period based on engineering records, i.e., a billing engineer, and utilized in the modeling of ANN. Other information involves cost abstracts of rigid and flexible pavements, maintenance schedules, and renewal cost information. The data collection process includes the identification of the area under the study, identification of representative sections of the roadways, and the arrangement of the information about costs. The traffic observations and survey-based approaches are also taken into account to comprehend the conditions in the roadways in some cases. The data obtained is authenticated and formatted in a way that it can be further analyzed regarding lifecycle and predictive analysis.

5. Pavement Alternatives Considered

This research examines the two main types of paved surfaces, rigid and flexible. The research measures costs associated with each type of pavement through the phases of initial construction vs. maintenance routine(s) as well as their overall long-term performance combines these cost components related to earthwork, pavement base layers, & maintenance were used to evaluate whether or not both types of pavements were equally economically feasible and sustainable over a long period of time given that they were subjected to similar environmental conditions.

6. Life Cycle Cost Analysis (LCCA)

In this study, Life Cycle Cost Analysis is employed as the primary economic analysis tool. The analysis is done within a time span of 30 years, to take the initial cost of construction as well as the long term cost of maintenance. In the model, the inflation rate is estimated at 5% and the discount rate is 12% to cover the future changes in the cost and estimation of the present value. Annual maintenance cost, periodic renewal cost, inflated cost, discounted cost and cumulative lifecycle cost are determined in respect to each type of pavement. The procedure enables one to compare the total economic cost of rigid and flexible pavements and determine the break-even point at which either of the two becomes cost-effective as compared to the other.

7. Maintenance Strategy Evaluation

In evaluating Maintenance strategies, the analysis of how often and for what cost are the Routine and the Periodic Maintenance activities for each type of Pavement is necessary. The evaluation involves examining the frequency of maintenance required, what is the cost associated with the renewal of that Maintenance, and how the Maintenance performed will affect the long-term performance of the Pavement. Flexible Pavements generally require more frequent Maintenance than Rigid Pavements but cost considerably more to construct than to maintain in the long term. Ultimately, the Maintenance Strategy evaluation will give information about how Maintenance Strategies affect the Lifecycle Cost and sustainability of Highway Infrastructure.

8. Artificial Neural Network (ANN) Modeling

The Artificial Neural Network is employed to forecast the future maintenance cost with reference to past data. The ANN model is created in MATLAB with the help of Neural Network Toolbox. A feed-forward backpropagation network is generated with the training function of TRAINLM, the learning function of LEARNGDM and the performance function of the Mean Squared Error. This network has two layers and 10 neurons on the hidden layer. The data that is used as the input comprises 20 years of values of maintenance costs, and the model is trained to forecast the new trends of maintenance. The forecasting strategy improves the accuracy of future cost prediction and aids in improved maintenance planning.

9. Analytical Procedure

The analytical methodology for the study conducts a systematic series of actions beginning with selecting pavement alternatives and gathering data, making cost summaries, and calculating the lifecycle cost. After the LCCA results are complete, rigid pavement and flexible pavement costs are compared to determine a break-even point. The future maintenance cost predictions are made using ANN modeling, and the analysis of both types of pavement determines the long-term impact economically and sustainable construction practices. This combined process will use both current and future economic factors when determining the most appropriate method of highway maintenance.

5 CASE STUDY AND ANALYTICAL FRAMEWORK

The initial analytical environment is the Aurangabad Highway to Kolwadi Road research where the 20 years of maintenance cost data are selected as the ANN input and future maintenance projections. It looks at the behavior of annual maintenance cost, detailed maintenance cost of rigid and flexible pavement, periodic maintenance schedule, and the cost of periodical renewal in the chapter. This is aimed at learning about the behavior of the various pavement systems under a long concession period and how its maintenance needs impact on its long-term economic performance. In the case, the largest expenditures on rigid pavement are on concrete pavement and earthwork (39.13% and 18.70% respectively).

Fig 3. Bitumen spray

Fig 4. Road Site

In India, the Mumbai-Pune expressway is the second case of analysis where the total length of the expressway is roughly 95 km, with 5 major interchanges opened in 2002, making it one of the busiest corridors. The project was built with 6 lanes and has a total construction cost of Rs 16.36 billion (about $440 million), starting at Kalamboli in Navi Mumbai, ending at Kiwale in Pune, with the official inauguration occurring in April 2002, with the Maharashtra State Road Development Corporation (MSRDC) being responsible for the expressway's construction. The distribution of costs associated with the construction of rigid sidewalks, including concrete sidewalks is supported by large expenditures on construction materials, with concrete sidewalks accounting for 42.33% of overall mature expenditures, and earthwork accounting for 19.23% of mature expenditures. This case increases the ability to generalize the results obtained from the study and provides a clear connection between lifecycle cost and maintenance.

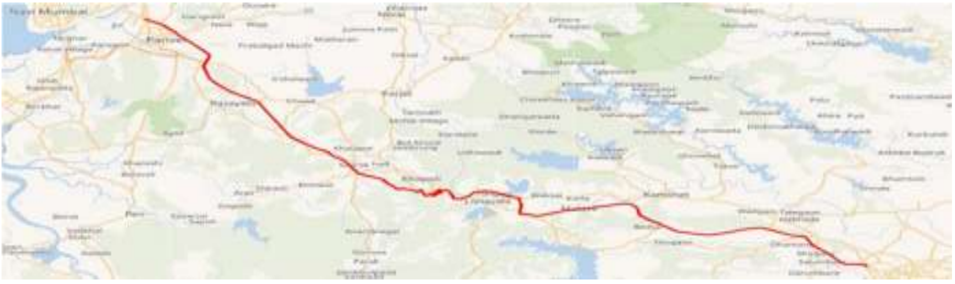


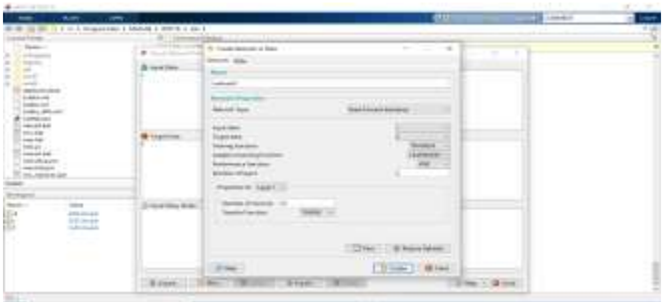
Fig 5. Mumbai –Pune Expressway: Route map

Table 1: Mumbai-Pune Expressway: Toll rates

vehicle type	Toll fee
Cars	Rs 320
Mini buses	Rs 495
Heavy-axle vehicles	Rs 685
Buses	Rs 940
Large trucks	Rs 1,630-2,165

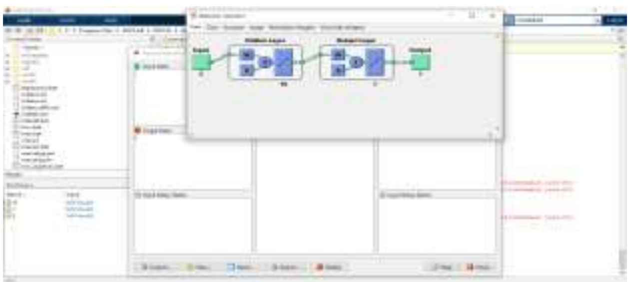
6. RESULTS AND DISCUSSION

The findings and discussion determine the effectiveness of highway maintenance strategies on the rigid and flexible pavements through life cycle cost analysis (LCCA). The results show that rigid pavements are more cost-efficient in the long run because of the reduced maintenance needs. The break even point is in 2029 when rigid pavements will exhibit better performance where the cost is reduced at a rate of about 12.93 percent by 2048. Sustainability and safety-related practices, such as the decrease in traffic jams and the amount of CO 2 released, are also mentioned as the significance of the research. Moreover, the Artificial Neural Networks (ANN) are employed to forecast the future maintenance costs and assist in proactive management and control of costs as well as the long-term highway management strategies.



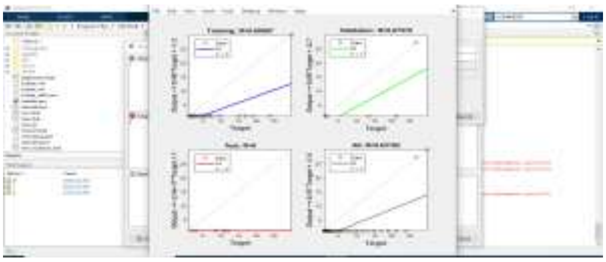
The MATLAB Neural Network Toolbox model, "network1," is a neural network model that has been created in the toolbox and consists of a feed forward-back propagation neural network trained by the TRAINLM algorithm and learning process created using the LEARNGDM algorithm. Mean squared error was used as the performance measure for this network model. The architecture contains two layers with ten neurons and TANSIG as the transfer function (i.e., activation function), thus enabling efficient prediction of inputs and patterns of target output data from input data.

- **Gives time (in terms of days) as input.**

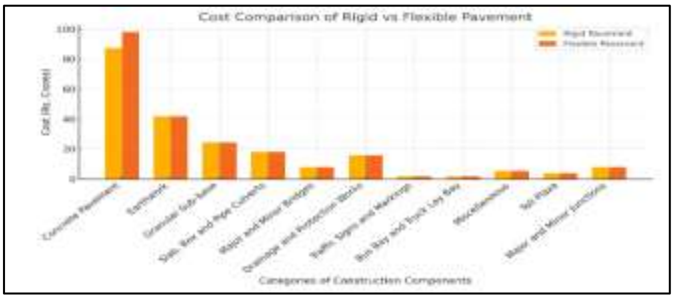


The diagram depicts a three-layered MATLAB neural network named network1; the input (5 neurons), the hidden (10 neurons), and the output (1 neuron) layers. The nonlinear learning uses the hidden layer to use weights, biases and activation. The final prediction is provided by the output, the weights and biases are adjusted in the course of training to reduce the error and enhance precision.

- **LCCA Results in MATLAB**

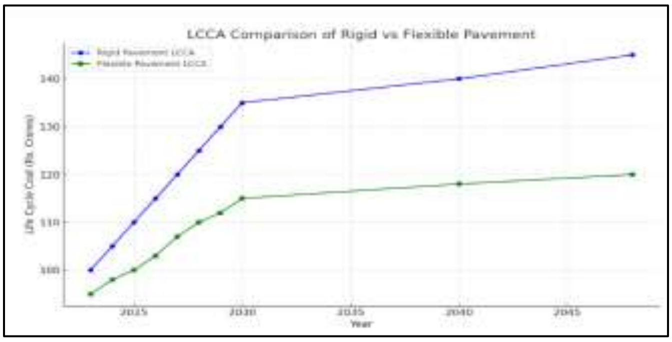


The figure displays the performance of a neural network implemented using MATLAB with four different types of plots: training, validation, test, and all together. Based on the coefficients of determination (R values), the train (R=0.60887) and validation (R=0.67576) datasets provided moderate predictions, while the test dataset (R=0) demonstrated poor generalization of the learned data. The total performance across all datasets provided a moderate R value of 0.63182, and indicated that the model was overfitted and required additional optimization to increase its overall accuracy.



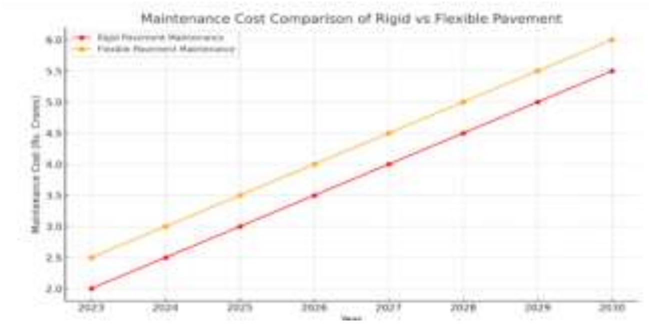
Graph 1. Cost Comparison between Rigid and Flexible Pavement

The graph is a comparison of cost elements of rigid and flexible pavements in which rigid pavements have higher initial cost because concrete pavement is very costly. Nevertheless, prices of such components as earthwork, sub-base, culverts, and others are comparable to both. Although the initial cost is increased, rigid pavements can be beneficial in the long term due to the need to be less maintained.



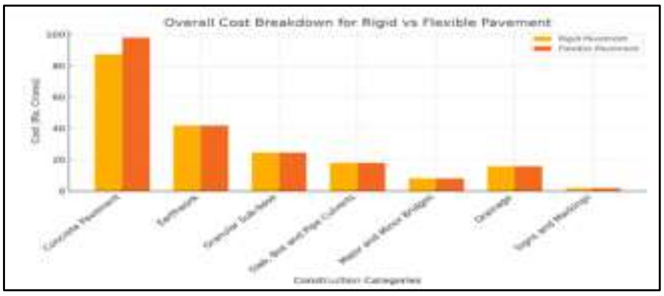
Graph 2. LCCA Comparison (Rigid vs Flexible Pavement)

The graph illustrates the Life Cycle Cost Analysis of rigid and flexible pavements as they age. In general, rigid pavements are more expensive in the beginning than flexible pavements; however, the increase in the price of rigid pavements over time is at a slower rate than the increase in the price of flexible pavements. Therefore, because of the rapid growth in costs associated with flexible pavements, rigid pavements are a more cost-effective and sustainable option to use throughout their entire lifespan and will save the most money in the end.



Graph 3. Maintenance Cost Comparison (Rigid vs Flexible Pavement)

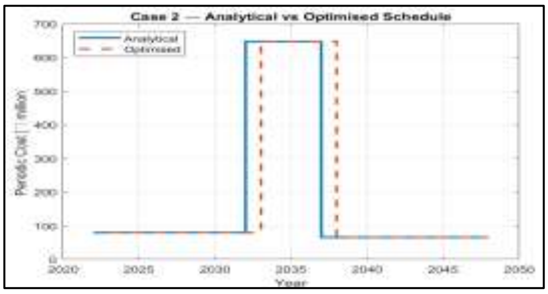
The graph depicts the trends in the maintenance costs of rigid and flexible pavements with time. The cost of maintenance of both cost gradually but flexibility pavements always costs more because it requires more frequent repair and maintenance. The stiff pavements are less costly in terms of long-term expenditure as they have less maintenance costs although the cost of their construction is high.

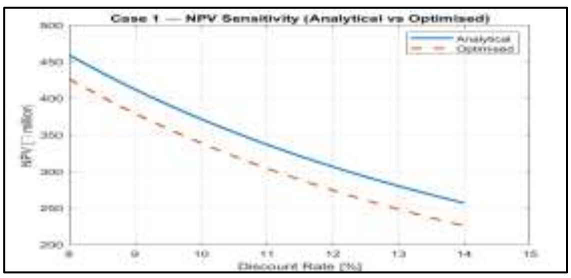


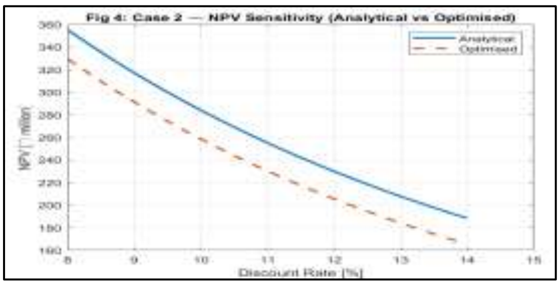
Graph 4. Overall Cost Breakdown for Rigid Vs Flexible Pavement

Total rigid and flexible pavement costs by construction component are presented in the figure. The higher cost of rigid pavements is primarily associated with concrete surfacing and drainage requirements, while flexible pavements typically have a lower cost and spread costs over numerous components. As such, even though the initial cost of constructing rigid pavements is higher than that of flexible pavements, the cost for all pavement components are fairly similar between the two types of pavement.

ANN Optimisation Results







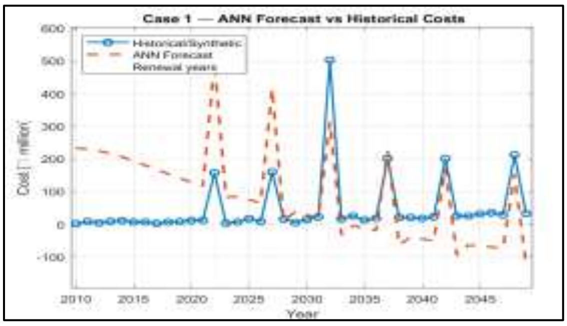


Table 1. Comparative Analysis Analytical Study Vs Matlab Optimisation

Case study	**Analytical schedule (yrs)**	**Optimised schedule (±1yr, gaps 4–6yrs)**	**NPV – Analytical (₹ Mn)**	**NPV – MATLAB Optimised (₹ Mn)**	**Savings**
Aurangabad → Kolwadi (47.8 km)	2022, 2027, 2032, 2037, 2042, 2048	2023, 2028, 2033, 2038, 2043, 2048	306.5	274.34	₹32.15 Mn (-10.49%)
Mumbai–Pune window (47.8 km)	2022, 2027, 2032, 2037, 2042, 2048	2023, 2028, 2033, 2038, 2043, 2048	230.02	205.62	₹24.41 Mn (-10.61%)

7. CONCLUSION

This paper confirms that cost, safety, and maintenance are not the sole aspects that should be considered in isolation to develop effective highway construction zones. A realistic and viable highway management system should incorporate the element of feasibility analysis, environmental and safety analysis, maintenance plan, lifecycle economic analysis, and proactive tools. The research indicates that highways play a major role in connectivity, trade, emergency management and development of regions, yet the environments surrounding their construction and maintenance are extremely dynamic and multifaceted. The current feasibility practices fail to respond to the risks and long-term impacts of highway construction zones in a manner that is integrated. The study will be organized in the framework of case studies and life cycle cost analysis as well as cost prediction of future maintenance, which will make it a more comprehensive model of decision-making in road infrastructure management.

The results of the analysis clearly indicate that rigid pavement is more economical than flexible pavement in the long-term economic perspective. In spite of the fact that rigid pavement has a higher initial build up cost, its less maintenance requirement alters the lifecycle outcome after the break-even year of 2029. In one analytical comparison, rigid pavement is reported to be cheaper by 10.39% and in another by 12.93% with a lifecycle of 30 years with 5% inflation and 12% discounting. The ANN element also fortifies the study by providing a predictive mechanism on forthcoming maintenance cost planning by a MATLAB based backpropagation feed-forward network using TRAINLM, LEARNGDM, and MSE. Generally, the paper concludes that integrated feasibility management with the aid of lifecycle economics and predictive analytics has the potential to enhance sustainability, lessen the long-term maintenance load and provide more powerful strategic direction in the highway infrastructure planning and maintenance.

8. PRACTICAL IMPLICATIONS

- Highway agencies need to consider pavement alternatives based on full life cycle cost analysis as opposed to depending on initial cost of construction.
- In highway construction zones, economic, environmental, operational, and safety considerations should be incorporated in one framework in terms of feasibility management.

- Maintenance planning is an activity that should be considered as a strategy since reduced demand in maintenance over the long term can yield great success in enhancing the sustainability of a project.
- Using a neural network (ANN) based prediction tool can provide a valuable resource for agencies as they plan for and budget their future maintenance costs.
- In large corridors, longer-lasting pavement systems can be more useful in the long run because it will lower the frequency of interventions, user inconvenience, and escalation of costs.
- Such integrated analysis can assist policy and regulatory bodies to enhance standards on safety, sustainability and cost management in long term in highway construction zones.

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