GABM - Empowering the Micro Bridge Inventory Owners

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Abstract

World over Bridge Management [BMS] implementation is tilted towards owners having large bridge inventories. Implementing BMS is difficult for owners with less than 100 bridges. In certain pockets of India, most of the facilities and skills needed are available. The research was aimed to evolve BMS to suit the small inventory owners. The resultant application "Global Analytics for Bridge Management" [GABM] is aimed at empowering micro bridge inventory owners fulfilling the key objectives of BMS. Sustained research to provide thousands of micro-owners in India was a herculean task. GABM allows partial integration of BMS with the Bridge Information Model [BrIM]. Integration with Short term Structural Health monitoring allows risk-free monitoring of bridges in need of rehabilitation. Freedom to choose from the various functionalities in the GABM software does not result in the user losing any technical advantages of BMS. Software development for GABM was challenging. GABM renders operational ease in all formats of operating systems.

Keywords: Global Analytics for Bridge Management [GABM]; Bridge Information Model [BrIM];3D geometric model;3D photogrammetry model; Short term Structural Health monitoring[STSHM]; LCCA; Sustainability.

1 Introduction

A major role of any Bridge Management System (BMS) is to manage and organize data related to all the bridges on a particular network. BMS ensure to collate data regarding periodic inspection reports for a bridge and keep track of inventory records to facilitate better decision-making during maintenance and rehabilitation for the entire service life of the bridge. Bridges deteriorate over time, during their service life. Bridges, therefore, need continuous inspection and maintenance to ensure their structural integrity, and in turn, ensure user-safety during their travel on the bridge. Maintaining bridges is a multi-faceted operation that requires both domain knowledge and bridge analytics techniques over large data sources. Although most existing bridge management systems (BMS) are very efficient at data storage, they are not as effective at providing analytical capabilities or as flexible at supporting different inspection technologies. Without data and data analysis, bridge management would be little more than ad hoc reactions to the most urgent crises, rather than a well-planned, proactive process. It is also true that at times, data collection and analysis are performed in the required periodicity. Even rare missing one inspection cycle can result in erroneous analysis.

Global analytics for Bridge Management [GABM] is a data-driven approach that has been used to improve the safety and performance of bridges. The use of analytics in bridge management dates to the late 20th century when engineers in the United States began using bridge data to analyze and control the structural integrity of bridges. In the early 21st century, bridge engineers used computers to analyze bridge data and develop

predictive models to detect and prevent bridge failure. In recent times, the use of analytics for bridge management became more widespread as engineers used analytics to identify and prevent corrosion, fatigue, and other structural issues. In the 21st century, analytics for bridge management has become more sophisticated, with more sophisticated software and hardware being used to collect and analyze bridge data. Analysts are now able to develop models to predict bridge failure and maintenance needs and analyze bridge performance to identify areas of improvement. The use of analytics for bridge management has had a significant impact on the safety and performance of bridges around the world. As a result, the number of bridge collapses and fatalities due to bridge failure has decreased significantly in recent years [2,3,11]. Additionally, bridge inspections and maintenance costs have been reduced, allowing for the efficient use of funds for bridge management.
Global analytics for bridge management is an important tool used to help bridge owners, engineers, and other stakeholders make well-informed decisions about bridge maintenance and repair. By utilizing predictive analytics, bridge owners can identify and address potential risks before they become major problems. Analytics can also provide detailed information about the various elements of a bridge, allowing engineers to optimize maintenance and repairs for maximum efficiency.

The research aimed to evolve a solution within India that can help to integrate new and innovative technologies and bring various needs of users to the front. All this innovative approach was designed not to lose focus on the key objectives of Bridge Management. The resultant application "Global Analytics for Bridge Management" [GABM] is aimed at empowering micro bridge inventory owners fulfilling the key objectives of BMS. It is internet free and has an efficient database structure. It is also easy to implement. GABM allows partial integration of BMS with the Bridge Information Model [BrIM] by enabling the use of a 3D geometric model and the creation of a 3D photogrammetry model for distressed elements to define the Geo-spatial location of distress. Integration with Short term Structural Health monitoring allows risk-free monitoring of bridges in need of rehabilitation. Most of the functionalities in the GABM software are not mandatory. Mandatory data collections ensure that BMS key objectives are met without activating a single other functionality. Software development for GABM was challenging as it involved modifications in the BMS protocol to ensure it is totally internet free. The innovative approach renders operational ease in all operating systems i.e., Windows, macOS, Android, iOS, and LINUX.

UBMS research group focused on global analytics for bridge management, which helps bridge owners understand their bridges' performance and set goals for future bridge maintenance and repair. Such as:

a. Increase efficiency – Analytics can help bridge engineers better understand the structure of bridges, identify potential weaknesses, and utilize data to plan for maintenance and upgrades in a timely and cost-effective manner.
b. Improve safety – Analytics can be used to identify potential risks and hazards associated with bridges and quickly alert engineers to any changes in the structure or environment that could affect safety.
c. Develop better bridge designs – Analytics can help bridge engineers develop more efficient and cost-effective bridge designs. By analyzing data, engineers can identify areas of the bridge design that may need improvement and identify areas that could benefit from creative solutions.
d. Monitor bridge performance – Analytics can be used to monitor bridge performance and detect any changes that may be indicative of structural weakness. By collecting and analyzing data in real-time, engineers can quickly identify any potential problems and take the necessary steps to address them.
e. Reduce maintenance costs – Analytics can help bridge engineers better understand the structure of bridges and detect potential problems before they become costly. By using analytics to better understand bridge structures, engineers can plan for routine

maintenance and upgrades, helping to reduce maintenance costs.

2 Database structure

Global Analytics for Bridge Management is a comprehensive database designed to manage and track bridge performance on an international level. It is designed to provide a comprehensive view of bridge performance and provide users with detailed analytics to make informed decisions. The Global Analytics tool only allows for the entry of a meagre 35 or so data fields, all of which are crucial for the production of the important findings required for the full operation of the BMS. This limited input data field enabled us to do away with the complex database structure of traditional BMS, which necessitated a costly investment in either a physical server or a cloud server[2,4]. Additionally, the requirement for an internet-driven BMS was removed by these constrained inputs. With the introduction of the Global Analytics tool, two major obstacles to the implementation of BMS in any department: small, micro, or large inventory; have been removed. Results for the fundamental main operations anticipated of every BMS are produced by this tool, such as risk analysis and assessment. To accomplish effective fund management, fund allocations are optimized along with the assignment of technically excellent ranking and priority methods.

2.1 The database structure consists of the following main screens:

a. Log In and Instructions Screen-

To access the Global Analytics for Bridge Management system, enter your username and password. Once you have logged in, you will be able to view the instructions and user guide with the Global Analytics for Bridge Management system.

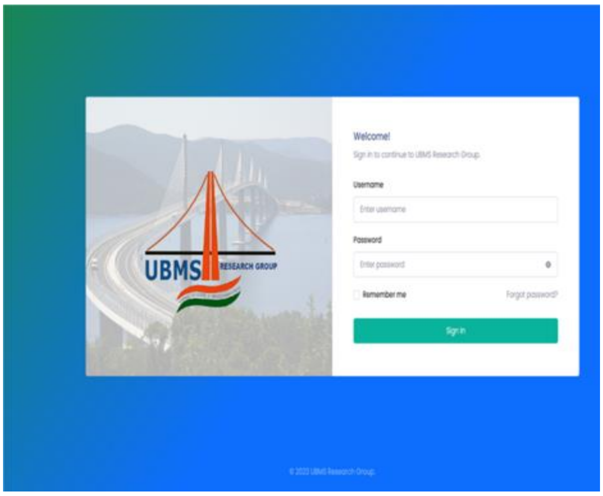

Figure 1. Login Screen

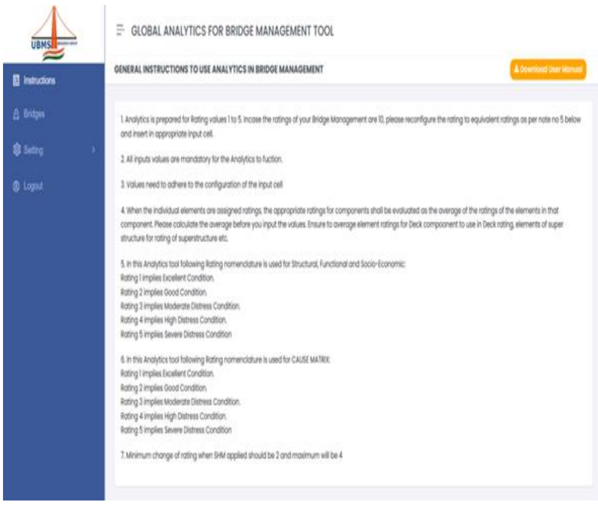

Figure 2. Instruction Screen

b. Bridge Identity Screen-

This bridge identity screen is designed to help bridge management teams analyze data from across the globe. The screen helps bridge managers to identify potential problems and opportunities for improvement, and can be used to develop strategies for bridge management. This screen contains data about each bridge, such as its length, span length, and a total number of spans.

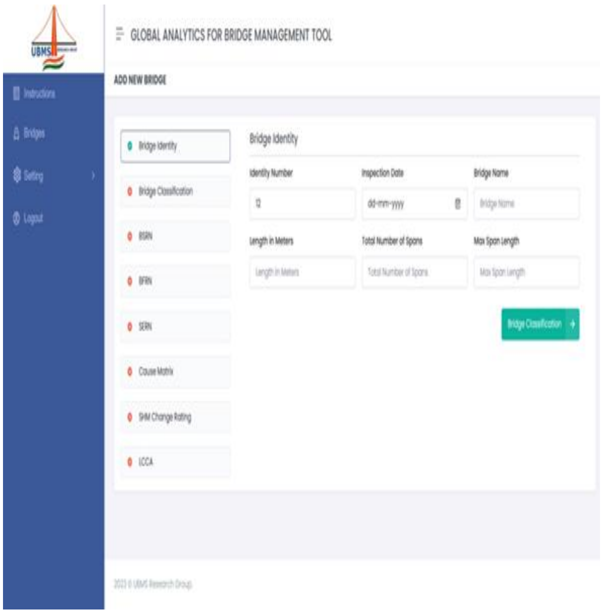

Figure 3. Bridge Identity Screen

c. Bridge Classification Screen-

The Bridge Classification Screen for Global Analytics for Bridge Management is a tool used to evaluate the condition of bridges and identify maintenance needs. The screen considers factors such as the age of the bridge, the type of road, the traffic lane & load it carries, and its condition. The Bridge Classification Screen is a valuable tool to help bridge owners and managers understand the condition of their bridges and plan for maintenance and repairs.

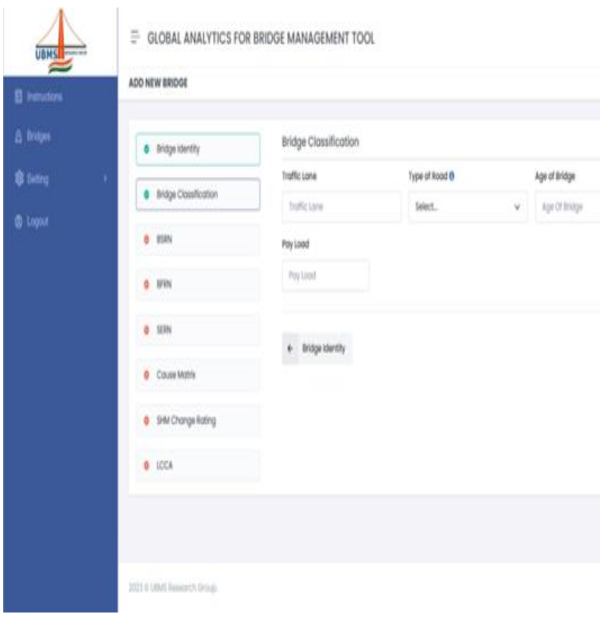

Figure 4. Bridge Classification Screen

d. Bridge Structural Ratings Number (BSRN) Screen -

The screen for Global Analytics for Bridge Management provides a user-friendly interface for quickly and easily inputting bridge structural rating numbers into the system. This screen allows users to enter ratings for decks, superstructure, substructure, and scour; and the system will automatically generate a report based on the information provided. The report can also be used to identify areas of concern and prioritize bridge repairs. The classification assigned to a bridge can range from ‘Excellent’ to ‘Critical’, with each classification requiring a different level of maintenance.

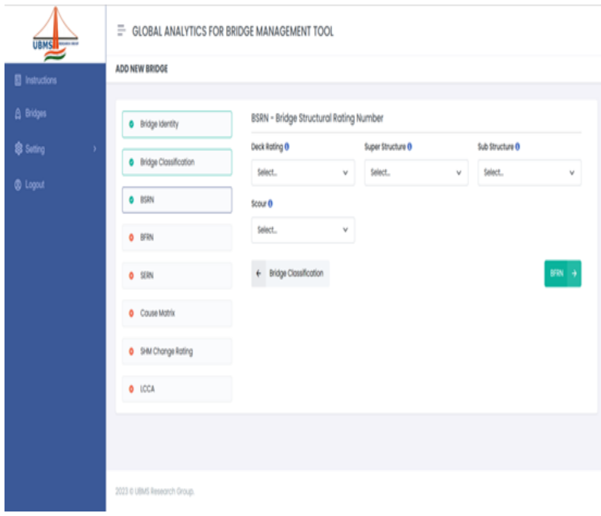

Figure 5. BSRN Screen

e. Bridge Functional Rating Number (BFRN) Screen-

It is a tool used by bridge engineers and transportation planners to assess the condition of bridges and prioritize maintenance, repair, and rehabilitation needs. The BFRN Screen-for Global Analytics for Bridge Management is a web-based system that allows users to quickly and easily analyze bridge data from a variety of sources, including deck geometry, vertical clearance, waterway and average daily traffic data (ADT). It is assigned from ‘Excellent Condition’ to ‘Critical

Condition'. The system is designed to help bridge engineers and transportation planners identify bridge conditions and prioritize bridge maintenance, repair, and rehabilitation needs.

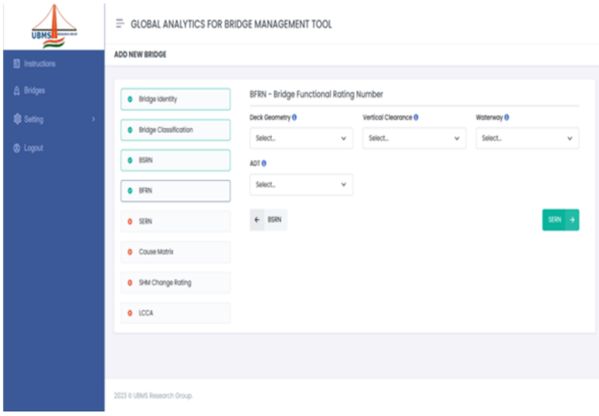

Figure 6. BFRN Screen

f. Socio-Economic Rating Screen (SERN)-

It helps to measure the impact of bridge management decisions on a local or global economy. The tool is designed to identify the financial, social, and environmental impacts of bridge management decisions and to prioritize projects based on their overall economic benefit. The classification assigned to a bridge can range from 'Excellent Condition' to 'Critical Condition'.

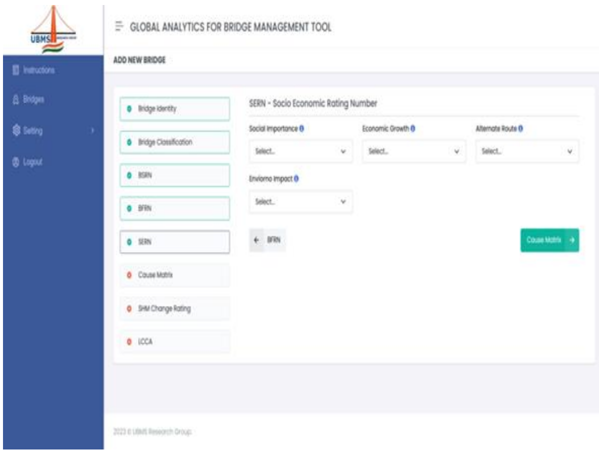

Figure 7. SERN Screen

g. Cause Matrix Rating Screen-

The Cause Matrix Rating Screen for Global Analytics for Bridge Management is a tool used by bridge engineers and analysts to assess the condition of bridges. The Rating Screen is composed of three categories: Mechanical ratings [Impact, Abrasion, Erosion, Cavitation, and wear & tear], Physical ratings [Temperature, Shrinkage, Settlement], and Chemical ratings [Chloride, Sulphate, Carbonation, Alkali-Aggregate Reaction]. For each of the categories, the user rates the bridge on a scale of 1 to 5, with 1 being the Excellent condition and 5 being the Failed condition. The ratings are then used to generate a bridge report that provides an overall score and shows areas of concern. The report can then be used to inform decision-making and guide bridge maintenance and repair.

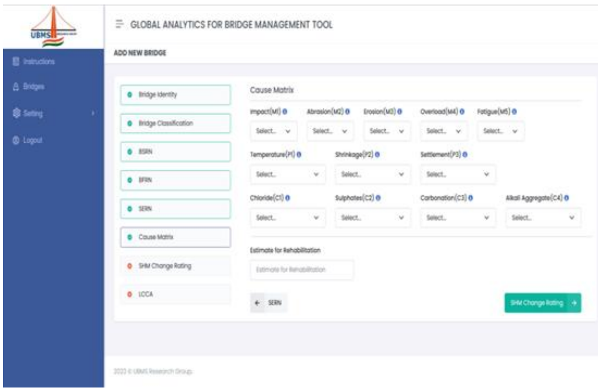

Figure 8. Cause Matrix Rating Screen

f. Risk Analysis Result Screen-

The final risk analysis result screen is used to assess the risk to bridges around the world. The data includes the bridge's location, type, condition, and risk level. It also displays the estimated cost of repairs, Design Service Life, Balance Service Life (BSL), Absolute Balance Service Life (ABSL), Median Service Life (MSL) and maintenance required, the estimated number of years before the bridge needs repair or rehabilitation, and any other potential risks associated with the bridge. The results are displayed in a graphical format, allowing users to quickly identify and prioritize their bridge maintenance and repair projects. Additionally, the results can be drilled down to provide more detailed information about each bridge, including a history of inspections and repairs, as well as the impact of any proposed changes.

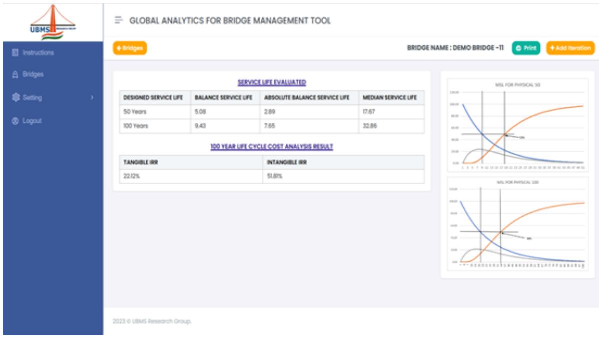

Figure 9. Result Screen without SHM

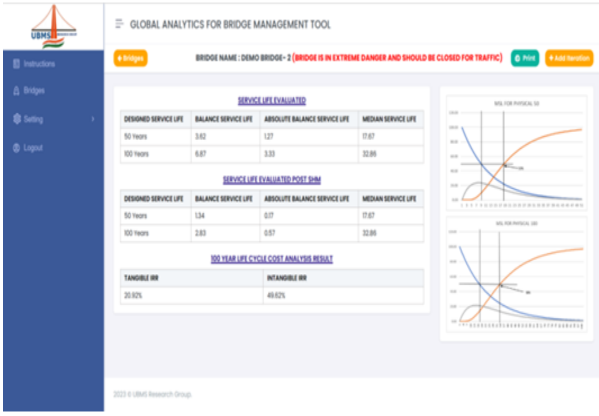

Figure 10. Result Screen with SHM

3 Short-term Structural Health Monitoring

Structural Health Monitoring (SHM) for bridge management is an important tool for global analytics. SHM is a set of techniques used to detect and monitor the health of bridges, allowing for the timely detection of faults and damage. This allows for the rapid assessment of bridge conditions, allowing for the proactive management of bridge maintenance and repair. SHM involves a variety of sensors, data acquisition systems, and analysis methods to detect and identify faults and damages. These can include both active and passive SHM systems, which are used to detect changes in bridge performance and to develop predictive models for bridge performance [1,4,5,8]. SHM also allows for the implementation of advanced analytics and machine learning algorithms to detect and identify bridge performance issues. By combining data from a variety of sources, SHM can help bridge managers to better identify risks and issues and develop more effective management strategies. Collecting and analyzing the data collected from a structural health monitoring system can be a challenge due to the amount of data and complexity of the analysis. Also, the accuracy and reliability of the results from a structural health monitoring system depend on the quality of the data and the accuracy of the algorithms used to analyze the data. Structural health monitoring systems require regular maintenance to ensure the accuracy of the results.

In the Global Analytic Bridge Management tool, the final and most crucial phase is ranking and prioritization. The user can select a high-risk bridge at this phase. The departmental budget and the estimated cost of repairs for the bridge are used to determine the rank of the bridge. The team determines the bridges for which remedial help is offered based on rating and priority procedure. Other bridges are added to a list of Bridges Under Observation and Monitoring (BUOM) for which intervention is not offered. Short-term Structural Health Monitoring (STSHM) is used for additional data collecting on the list of Bridges Under Observation and Monitoring (BUOM) for 3 to 4 monitoring periods, not to exceed 72 hours each, over the course of a full year. Such STSHM offers crucial information regarding the performance decline seen in highly damaged bridge structure elements. In order to gauge how quickly the bridge is deteriorating, the Global Analytic tool records the degree of performance degradation. On the basis of STSHM action observations, BSL and ABSL are once more assessed. We are able to move away from a decision-making process based solely on engineering judgement; thanks to the integration of SHM and UBMS. We introduce a more responsible scientific approach to BMS with the real recording of performance degradation and its application to the evaluation process.

4 Partial integration of BMS with the Bridge Information Model [BIM]

The integration of the Bridge Management System (BMS) with the Bridge Information Model (BIM) is an important technology that helps bridge owners and designers make informed decisions regarding bridge maintenance and management. By integrating the BMS and BIM, can access comprehensive data about bridge structures, as well as up-to-date information about bridge conditions. This information can be used to plan and evaluate bridge maintenance, repairs, and upgrades [2,10]. Integration of BMS and BIM also allows for easy share information about bridge conditions with other stakeholders. This makes it easier to coordinate and ensure that the bridges are properly managed and maintained. Furthermore, the integration of BMS and BIM allows bridge owners and designers to identify potential risks and vulnerabilities associated with the bridge[3,4,7,11]. This helps proactively address any issues before they become major problems. Overall, the integration of BMS and BIM can provide valuable insights into the health of their bridges and enable them to make more informed decisions regarding bridge maintenance and management.

By using an integrated strategy to establish the precise site of distress in the elements indicating severe distress, more advancements within BMS are made possible. Data from periodically gathered digital imagery are extremely important for understanding the real rise in visible signs of distress. The Global Analytics tool can produce one of two kinds of outcomes from digital imagery. There is the ability to upload, save, compile, and retrieve 3D geometric models of whole bridges outlining severe distress elements. Using Meshroom photogrammetry software also makes it possible to record individual element records for slight signs of distress in that element. The need for very high-capacity data storage is no longer necessary because photogrammetry methods are only used on extremely distressed parts. According to the figures below, individual records take up a few hundred KB of data storage space each. The Global Analytics tool can be used to collect crucial data on the precise geospatial location and nature of distress spread once digital imaging has been employed.

Most of the barriers identified and put out by various authorities as reasons why BMS should not be implemented have been removed according to URG. The global application of the Global Analytics tool includes all BMS, all nations, all regions, and all volumes of inventory [Micro to Macro]. Our research department remains committed to ensuring continual innovation. The goal of the current study is to develop an algorithm that will translate observed symptoms into a Cause matrix. The findings of this study will bring about a significant paradigm shift in bridge management on a global scale. URG is dedicated to conducting research in India to offer solutions throughout the world. We keep working and moving forward with the goal of bringing inventory technologies and utilizing them to improve bridge management procedures globally.

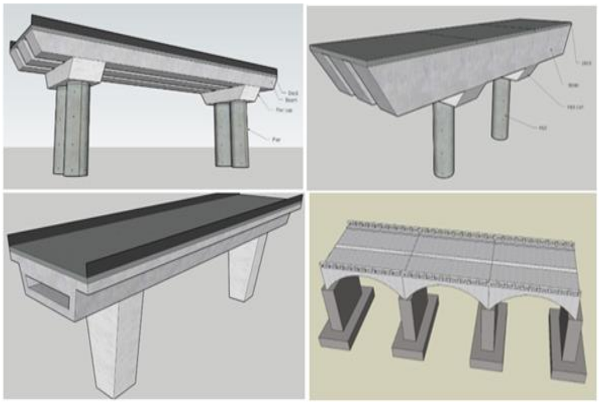

Figure 11. 3D Model Generated from Geometrical Details

Figure 12. Model Generated from Photogrammetry Tool

5 BMS Protocol – Operating Systems

Global Analytics for Bridge Management tool known as GABM is a web and desktop application using the Core PHP framework along with MySQL DB. The front end is in HTML, jQuery with PHP and backend we used MySQL. This application is developed in such a way that the response should be quicker, it is achieved by using certain query optimization techniques. To make this application platform independent or run on any OS like Windows, Linux, or macOS, we are using “Electron client” on top of the PHP. It works as a desktop application on the client machine.

In order to make the application responsive, we are using Bootstrap CSS with HTML, we also used jQuery for scripting on the client side.

The subscription of the application is for one machine, it will not be installed on another machine with the same subscription. This is done using the mac-Id of the installed machine.

6 Conclusion

In the greater transportation system, bridges play a significant role. The Bridge Management System (BMS) is an integral feature of long-term asset management and a crucial component of the overall asset management process. The goal of management is to maintain the bridge by spotting flaws and making the necessary repair interventions as needed to maintain traffic safety. The gathering of inventory and inspection data, component repair, rehabilitation or replacement, and funding allocation prioritization are the main duties of bridge management. A BMS is a tool for managing bridge data so that maintenance plans can be created while staying within budgetary constraints. Data storage, cost and deterioration models, optimization and analysis models, and update functions are the four fundamental parts of a BMS. First and foremost, the state that is deteriorating needs to be determined using the data gathered from visual examination or remote sensing etc.

The user is able to understand the balance of service life and risk with the help of the advanced software application for analyzing analytics in the bridge management system, which also assures optimal fund allocation. Sustainability is guaranteed without sacrificing the region's economic growth under the effect of the bridge because of the integration of Structural Health Monitoring, Digital Imagery, and life cycle cost analysis with BMS within the Analytics tool. Without compromising any of the technical requirements of bridge management, this application is made to be able to test the functionality in all geographical regions and all nations of the world.

The Global Analytics for Bridge Management System provides a comprehensive overview of bridge conditions and performance across multiple countries. The use of Global Analytics for Bridge Management has the potential to revolutionize bridge engineering and management. By leveraging data-driven analytics, bridge engineers and managers can gain insight into bridge performance, create more reliable bridge designs, and optimize bridge maintenance and repair. Additionally, analytics can help bridge managers identify safety issues, improve efficiency, and reduce costs associated with bridge maintenance and management. Ultimately, data-driven analytics can help bridge managers make informed decisions and ensure maximum safety and reliability. In conclusion, Global Analytics for Bridge Management offers a comprehensive and integrated approach to bridge management. It provides a comprehensive database structure and structural health monitoring system to enable bridge owners and operators to better manage the bridge assets. Additionally, the partial integration of BMS with the Bridge Information Model (BIM) provides powerful tools to better understand and manage their bridges. The Global Analytics for Bridge Management provides an effective and comprehensive approach to bridge management and can be used as a platform to improve bridge safety, reliability, and performance.

7 Reference

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