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Smart Sustainable Construction Lifecycle Management

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***Abstract*—The paper discusses the design and implementation of a system for Smart Sustainable Construction and Lifecycle Management. The current state of our world is under stress due to factors such as population growth, economic expansion, and increased demand for natural resources. To ensure that life can continue in the present, it is imperative to establish a sustainable cycle without causing harm to the environment or depleting the sources of resources. Sustainable construction aims to apply the principles of sustainable development to the construction industry, which is one of the major consumers of natural resources. Smart solutions for the construction industry involve the use of smart systems to revolutionize and accelerate sustainability in the construction process. This study presents one such application for smart sustainable construction lifecycle management, which can be utilized by the construction industry to manage their projects in a more efficient and effective manner.**

***Index Terms*—Smart, Construction, Sustainable, Environment, City.**

I. INTRODUCTION

Our planet, which is home to over 7 billion individuals, is currently experiencing a significant transformation. The pressure to fulfill the needs of a rapidly expanding population and the growing demand for essential resources such as clean water, energy, and infrastructure is having a significant impact on the ecosystem. The trend of urbanization is leading to both social and environmental challenges. In India, for example, 31% of the population now resides in urban areas, with people moving there in pursuit of improved living conditions, healthcare, and educational opportunities, as well as a higher standard of living. This trend is expected to continue in the coming years, with the population of cities projected to grow by almost 50% by 2030.

Utilizing recyclable and renewable resources in construction sector while reducing energy use and waste output is known as sustainable construction. Reducing the environmental impact of construction is the ultimate goal of sustainable design. The issue doesn't go away after the building project is finished; during the course of the structure's lifespan, the design of the building should likewise have a minimum influence on the environment. This means that the building should be designed with components and materials that continuously affect how the structure affects the environment. Energy-efficient roof hatches on the rooftop, solar panels, enough insulation to avoid heat loss, and reducing energy consumption from the grid, which is mostly derived from fossil fuels and durable building materials, can be some of these.

Smart construction, an integral part of smart cities, aims to revolutionize the construction industry through the use of robots to lower project costs, improve project precision, reduce waste, and accelerate resilience and sustainability. Smart construction is composed of smart construction objects (SCOs), which are construction resources (e.g. machinery, tools, materials, and structures) that are made smart with sensing, computing, networking, reacting and communication abilities so that they have autonomy and awareness, and can interact with the vicinity to enable better decision making. In order to efficiently transmit safety-related information to safety officers and employees, a comprehensive and proactive system connected with numerous information technologies is established.

The drive to create this Smart Construction system is a result of the need to overcome the challenges previously mentioned. This system aims to address these critical issues and ultimately achieve sustainability.

II. PROBLEM DEFINITION

Special consideration must be given to smart sustainable construction. More than just using recyclable and renewable materials and minimizing energy use and waste during construction are all part of the idea of smart sustainable construction. Additionally, the building's design ought to have little effect on the environment during the course of its existence.. The Smart Construction System aims to provide solutions to these issues by implementing real-time site monitoring, efficient vehicle routing to prevent delays in transporting materials, enhancing construction safety, and improving project management.

III. LITERATURE SURVEY

The literature review helped us to understand the research that was done previously on topics related to our project. We scanned through a number of research papers in order to understand the methods used in the already existing systems and their disparities.

The authors of the paper [1] have conducted a comprehensive review of the various methodologies and challenges in the field of construction safety. They have highlighted the utilization of IoT technology in construction sites, through the use of devices and sensors mounted on construction equipment, to ensure the safety of workers by providing real-time monitoring and notifications of potential hazards. The authors have identified various sensing technologies, such as Gyroscope, accelerometer, infrared, thermistor, noise sensor, RFID, GPS etc. for physiological, environmental, proximity and location tracking of workers to prevent hazards such as falls from height, heat and cold, fire and explosion, noise, and being struck by objects. They have also discussed the use of location monitoring technologies such as Radio Frequency Identification (RFID) for preventing collisions with heavy equipment, video cameras for automated object identification, and PIR sensors to detect human entry. Additionally, the authors have reviewed various works done for labor safety monitoring, including the use of helmets equipped with gyroscope and temperature sensors that alert supervisors in case of dangerous angle and temperature variations, and the use of RFID tags for emergency call information from supervisors. However, these IoT devices also collect sensitive information such as physiological data and movement activities, which raises concerns about privacy. Therefore, the authors have emphasized the need for a strong network security infrastructure for short- and long-range communication to mitigate the risk of cyber attacks. They have also highlighted the importance of identifying the variables and creating the tools that can support the effective use of these technologies when deploying them on the construction sites.

The author of paper [2] discusses into the various techniques employed to enhance the construction levels of the city of Yiyang in alignment with the policy framework of the ”top level design scheme of Yiyang new smart city construction.” The author notes that Yiyang has received recognition in the form of the China government information award for its efforts in the field of construction, specifically for transitioning from traditional urbanization construction methods to a focus on urbanization for the benefit of citizens. The author highlights several key techniques utilized in Yiyang’s smart city construction efforts, including the development of a scientifically sound and representative evaluation index system and a constructor level indicator system. Additionally, the author notes that through academic research, a number of challenges have been identified in the measurement and evaluation of smart city construction progress, including a lack of uniformity in indicator systems and the presence of subjective factors. To address these issues, the author suggests utilizing principal component analysis to simplify measurement and analysis into five key categories: information infrastructure, unified support platform, people’s livelihood services, industrial support, and urban management. The author emphasizes the importance of utilizing the latest technology, such as IoT, cloud computing, and artificial intelligence, in the digital city construction process.

The author of paper [3] delves into the topic of a BIM-Integrated relational database management system, evaluating the life cycle cost of the system. They note that in traditional data management systems, data is often stored in paper form and input manually, leading to data loss and inconsistencies which in turn affect the accuracy of life-cycle costs. The author also cites existing literature on the combination of database management systems and BIM, arguing that these BIM tools by themselves are unable to completely manage all the data required for calculating building lifecycle costs. In response, the author introduces a novel technique that integrates a BIM authoring application, an RDBMS, a visual programming interface, and a spreadsheet system to organise, store, and extract relevant data from BIM models in order to carry out building LCCA. A relational database management module is created using a database management system, a visualised BIM-integrated module is created using a BIM authoring programme, and the two modules are combined to extract the data required for the BIM model using a graphic programming interface and a spreadsheet system. The author concludes by emphasizing the time-consuming nature of conventional building LCCA due to scattered data and complex calculations, and the potential for the BIM-integrated RDBMS to streamline this process.

The authors of journal [4] have conducted a study on the various Internet of Things (IOT) applications that are relevant to the construction industry. They propose the use of smart city construction, utilizing IOT devices or sensors for energy management, smart transportation, smart waste management system, smart lighting, and more. These IOT sensors employ different types of connection devices such as Global Positioning System (GPS), Radio Frequency Identification (RFID), ZigBee Module, Wireless Sensor Network, among others, which enable objects to be sensed and controlled remotely through existing infrastructure. Using Building Information Modeling (BIM) technology, the authors suggest providing a digital representation of functional and physical characteristics of building facilities through intelligent AEC (architecture, engineering and construction) tools, such as Primavera application for project management purposes, including planning, monitoring, controlling, and reporting. Additionally, they propose the use of GPS devices to obtain accurate and correct data about a specific area, instead of relying on traditional surveying methods, and using GPS-connected vehicles for faster delivery of construction materials. The authors also mention the use of Radio Frequency Identification (RFID) technology to locate specific targets through radio signals, as well as the use of Cement-Based Piezo-electric Sensors to monitor the damage of concrete structures. They conclude that the implementation of these IOT tools and sensors in the construction industry can modernize the entire sector, resolving issues such as delays in work, resource allocation problems, material wastage, and cost overruns, ultimately resulting in improved quality of construction.

IV. PROPOSED SOLUTION

Smart sustainable construction focuses on management of a construction project in a sustainable way focusing on the entire process from an early design stage towards the final product, and on the benefits and negative impacts that are to be expected during the life of the facility. It is therefore important to strike a balance between resource use, project cost so as to keep the project budget friendly. Smart solutions for the construction industry consist of smart systems for managing entire project. It focuses on managing the life cycle of any construction work, ensuring protection of the environment and natural resources, and their effective and sustainable management.

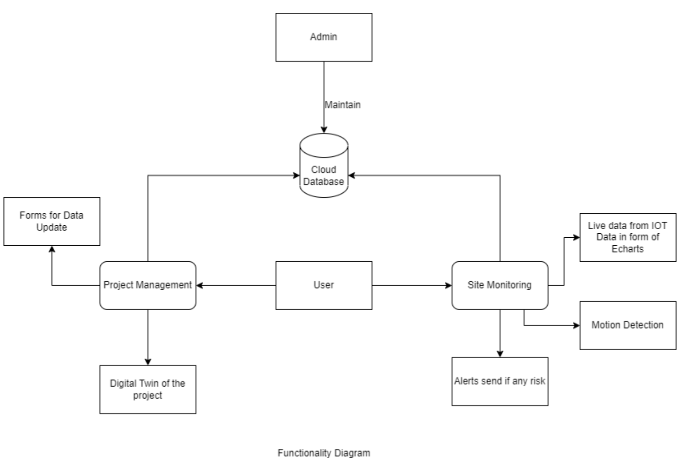

Fig. 1. Functionality Diagram

The proposed software system being developed is called a Smart Sustainable Construction Lifecycle Management System designed for any construction team. The proposed system includes various functionalities which can be used by the project management team and construction workers.
It uses IoT devices for site monitoring to have real-time insights on employees and machines. IoT sensors can also guide the machines with greater precision and minimal human involvement. The system also includes a vehicle routing module that can be used for optimizing transit routes and maintaining vehicles.
The application will also display digital twin of the project if the company provides the model. CRUD forms are the way used to store the site details in systematic manner Apart from this it also includes construction safety for assuring the safety and health of workers.

V. IMPLEMENTATION DETAILS

The process starts with getting information and requirements about the project from owners, contractors, subcontractors, designers and then learning about the process where the steps are divided into following parts:

A. Learning :

1) Learning about the Construction Lifecycle Management(CLM)
2) Acquiring knowledge about CLM that helps in making data models that are the entities which will be used to create JDL file, which is an essential part of the process as the project uses JHIPSTER Framework which is a free and open-source application generator used for quickly developing modern web applications and microservices using Angular or React and the Spring Framework.Some tables of the Data model used are Planning Information, Design Information, Construction Information, Utilization Information, Maintenance Information, Decommissioning Information, etc

B. Generating the Application interface :

1) After the JDL file is completed it is used to generate the Jhipster backend and ionic-app files which are made in Angular that is used to create the application for the project
2) Checking whether all the entities are generated in the backend.

C. Adding Functionalities,After Login :

1) Users have the access to the live data fetched using API from the IOT sensors placed on the construction site which is visualized in form of charts. Users are able to view the data in chart form, which helps to simplify the tedious process of going through information in just numbers.
2) Users also have forms to update the construction site information, add the site layout or designs or comments as and when required. Data will be stored in PostgreSQL which is a free and open-source relational database management system emphasizing extensibility and SQL compliance.
3) Maps are integrated for vehicle routing for fast and easy transport of materials which in turn helps to reduce the wastage of materials.
4) Vehicle Routing will be implemented using Optaplanner which is Open Source Constraint Solver which solves constraint satisfaction problems with construction heuristics and metaheuristic algorithms. OptaPlanner is written in Java and works in Kotlin and Scala too.

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5) Digital twin of the Building or project is made using ThreeJs library for site monitoring
6) Site monitoring using digital twin and IOT sensors is a major part in safety of works and needed for smooth process for construction projects.

The figures below are some of the screenshots from the prototype application. The Fig.2 shows the map view of Hyderabad location which is used for finding the best routes for the transportation of materials. The Fig.3 shows the charts for monthly cost estimation and temperature levels. The Fig.4 shows the digital twin which is a 3D model of the building that will be constructed which can be uploaded by tech leads.

Fig. 2. Map view of Hyderabad location

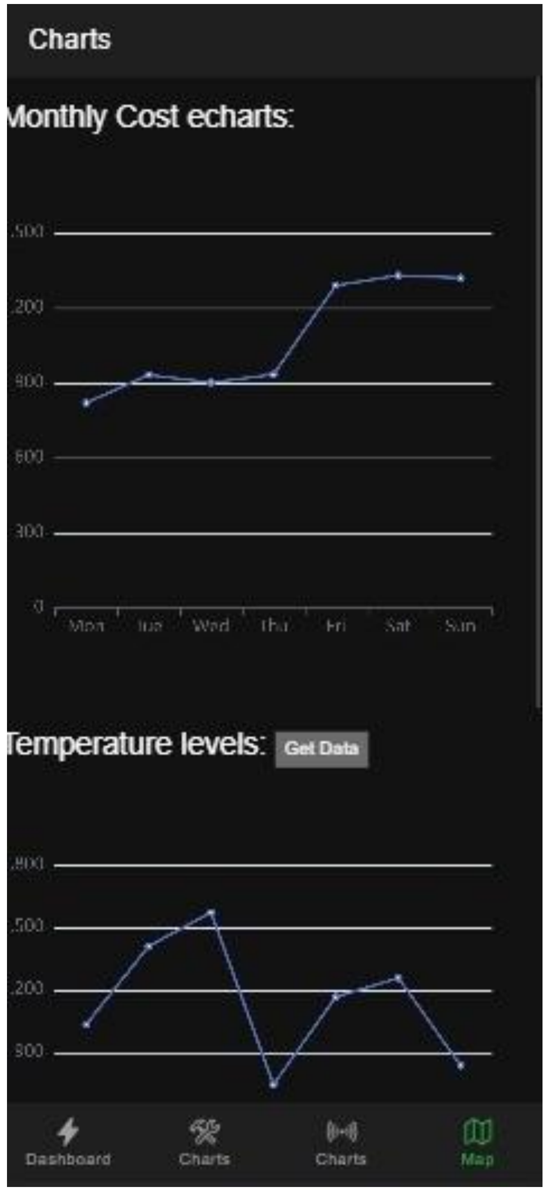

Fig. 3. Charts for pollution levels and cost

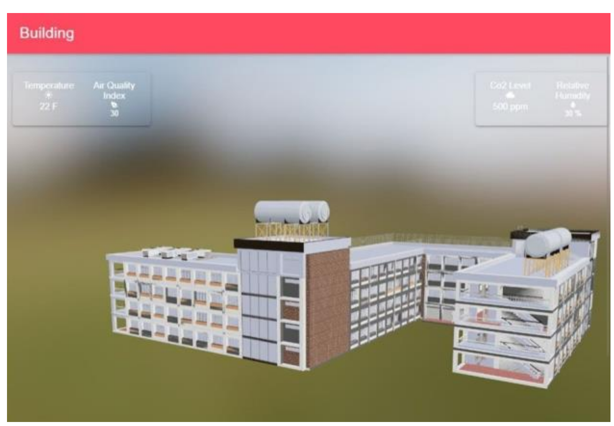

Fig. 4. Digital Twin

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VI. RESULTS

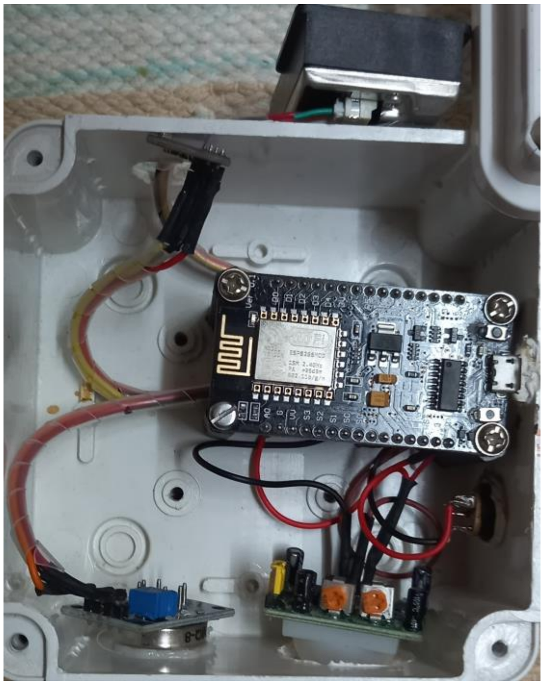

Fig. 5. Sensors

Fig.4 depicts a collection of IoT sensors that are designed to gather and transmit data from various sources, such as environmental conditions, physical movements etc. These sensors can be deployed on the construction site to provide real-time insights and enable more efficient and effective decision-making.

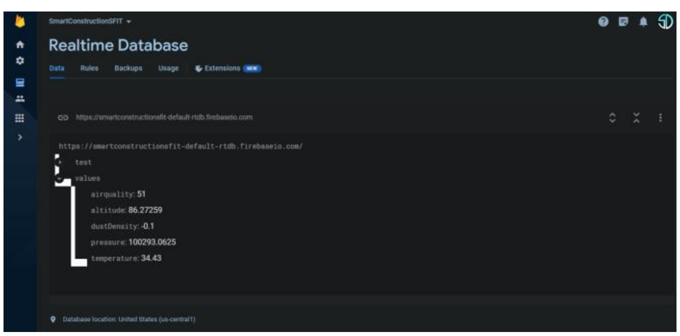

Fig. 6. Realtime Data through sensors

Fig.5 is a screenshot of Firebase dashboard that displays real-time data collected from IoT sensors, including the air quality index, altitude, dust density, pressure, and temperature. The dashboard provides an easy-to-read visual representation of this data, enabling users to monitor the status of the sensors and quickly identify any trends or anomalies. This information can be used to make informed decisions and take appropriate actions to optimize system performance and ensure efficient resource utilization.

VII. CONCLUSION

Hence, by intense research, designing and planning we have designed an application for achieving Smart and Sustainable Construction. The system can be used to manage the lifecycle of any construction project. Proper construction lifecycle management will help the construction industry to reduce costs, save time, attain sustainability and save our natural resources. The system also provides the construction safety module for the safety of construction workers. The system will be really helpful for the construction industry and to our society.

VIII. FUTURE SCOPE

Talking about the future scope, this project can be expanded by adding additional features, getting imporved accuracy. Furthermore there can be more work done in security to improve privacy. The UI of the app can be further improved to suit the consumers.

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