Development of IOT based prototype for Enhanced Scheduling and Inventory Management using 6D BIM

A thesis of Final Year Project

BE Civil Engineering

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This is to certify that the

thesis titled

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Abstract

Construction industry in the world face many problems regarding the inventory management of materials as material are the key elements of construction project. Manual monitoring of material stock is unreliable traditional method where we have inaccurate data and causes delay in project as well as economic deficiency because you don't know how much material is been used for a particular activity.so for this purpose we developed a prototype within the BIM environment to migitate the problem of cost overrun and inventory management system. BIM is basically a digital description of activates progress.

So BIM inventory monitor plugin (BIMS) was developed for real time monitoring of unconfined material i.e cement, sand and aggregate. The plugin was developed using a commonly used programming language C#, integrated with Autodesk Navisworks 2017 API. BIM software have open API where you can extend the functionality of BIM usage.

However, for tracking of real time data, a sensors prototype based on weight sensors was developed to capture real time data and also add the function of record management system for future investigation. Also we can check the material stock for upcoming activities as well foresee the timely order of materials. . Before development of plugin, expert's opinion were taken regarding its functionality and implementation in the market

Further limitations, and future recommendation are highlighted.

Table of Contents

List of Abbreviations

AEC	Architecture, Engineering and Construction
ICT	Information Communication Technology
API	Application Programming Interface
BIM	Building Information Modeling
CAD	Computer Aided Design
IOT	Internet of Things
WBS	Work Break Down Struvture
IFC	Industry Foundation Class
IT	Information Technology
JIT	Just in Time
EOQ	Economic Order Quantity
GDP	Gross Domestic Products
RFID	Radio Frequency Identification
CSCM	Construction Supply Chain Management
ABC Analysis	Activity-Based Costing Analysis

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CHAPTER 1

INTRODUCTION

1.1 Preface

In Architectural Engineering and Construction (AEC) Industry, inventory management and materials are linked in a specific way. Because total cost of the project is interjected by construction materials(Li, Hou et al. 2014). Inventory Management and material tracking is vital area of projects that have large investment. Complexity of project and size of project are the deciding factors for inventory management and material tracking on site(Li, Wang et al. 2014).

(S.S.Mahagaonkar and A.A.Kelkar 2017) Researcher define material management as "Material management is deliverance of required material at execution area with in given time constrain at specific amount so as to minimize the total project cost""

In large and complex construction project, the vital issue faced is to keep check on material ordered. The location of material and its tracking on construction site ensure the availability of material before execution of activities. The required quantity present for specific group of activities(Chen and Luo 2014).

Inventory management and location of material has been highlighted as one of the most important issue because materials are required on bulk quantities and unauthorized and improper checking of materials due to inexperience work power and traditional manual tracking method, make it difficult to keep track of every piece of material(Mohtat 2016).

The traditional manual methods have several limitations that results in the wastage of material and poor management of inventory(Mohtat 2016). Now advance technology has revolutionized the management field and also problem related to real time inventory management and material tracking on site are resolved to greater accuracy.

If large and complex project are managed properly, to not only save the project time but save the client financial resources(Li, Hou et al. 2014). So, availability of material on site is necessary for timely execution of project. Poor Inventory management will result in delayed project, increasing its cost and rescheduling of project work chart. For large projects, control over inventory and proper management of materials on site should be ensured for timely ordering of material as per schedule activities, on minimum cost.

Studies has revealed numerous limitations of classic manual tracking methods which is intensive exhaustive for labor, imprecise and subjected to human and systematic errors which results in wastage of excessive materials, delays in project execution schedule, minimizing the efficiency of projects, and the onsite positioning and quantity of materials lacks timely information regarding its current status. The traditional practices require excessive manpower and data acquired using such methods is inaccurate and inconsistent. as mood and skills of labor to track the materials decides its accuracy Moreover, outdated methods of materials tracking greatly depends on the data collection using handbooks manually. Sometimes, the data collected lacks consistency or uncompleted due to unwillingness of tired man power, causing distortion in keeping track of large quantities of materials. Manual tracking methods allows workers to use hand books for data collection which lack retracking of previously collected data records if misplaced incidentally.

With the advance of technology Inventory management and material tracking has been upgraded. New technologies has ease the tracking of material. Numerous researches are conducted that assimilated barcodes and Radio Frequency Identification (RFID) to systemize the data collection methods from construction sites. Data is acquired automatically using preset sensors connected by programming. Also, barcodes unified with Geographic Information System (GIS) to enhances the mass production of prefabricated components.

Inventory management field is more revolutionized using sensors-based technology. It consists of sensor-based equipment like Sonar or LiDAR that uses radio waves or electromagnetic waves, assists in location of materials using vision-based sensing, and wireless sensor networks, etc. The combination of multiple weight sensors provides a simple and economical tool for material quantification Furthermore, sensor-based technology provides artificial intelligence and automation in construction assisting a enhanced and collaborative platform, which is constructed by combination of hardware and software for data acquisition and processing , notably enhancing the tracking efficiency of on-site monitoring system and providing assurance and safety of construction materials.

BIM has been effectively creating tools for enhancement of construction industry. Every field of project is mostly covered using BIM models. In safety management, BIM can use RFID chips to track worker over large and dangerous construction site. In risk management, BIM linked to 3D models identifying risk of certain project, assisting in rectification of numerous problems before execution of specific activity. Contract management allows BIM resolving disputes that causes delays in project. In construction

management, data rich BIM models allows scheduling of activities and quantification of material, using Autodesk software (Navisworks, Revit)

1.2 Problem Statement:

We observe that large projects like Highways, Motorways and small. Town Construction requires greater quantity of materials for construction. These materials are provided in abundance to site throughout the Project. These materials are more likely to be stolen or wasted due to mismanagement. Also, pre-ordering of extra material or deficiency of planned quantity of material for respective activities results due to poor Inventory Management. These problems should be overcome properly to avoid any hinderance in the project progress.

BIM is modern tool assisting construction management, and has revolutionize the Architecture, Engineering and Construction (AEC) industries(Natalija Lepkova, Rana Maya et al. 2019). However, yet material tracking of unconfined material on site and planning of material in Inventory Management is to be explore.

A BIM based system is developed to manage the unconfined material that is cement. The planned quantity of respective material, schedule for group of activities will be compared to the actual material used and remaining material is checked. It will enable us to forecast the successive activity material stocking to migitate delay in project.

1.3 Objectives

The objectives of this research is

- To develop an IOT based prototype for real time BIM integrated stock taking to digitize inventory management.
- To integrate automated stock taking with 6D BIM to analyze relationship between available material stock on project schedule

1.4 Research Significance

Architecture, Engineering and Construction (AEC) industry continuously evolving with country development. Development not only facilitate the country physical but at present time it is 2nd biggest part of economic situation of Pakistan. Construction Industry contributes about 2.3 % to 2.8% to total GDP of Pakistan. The sector employs about 7.6% of labor force. Inclusion of more economical and accurate methods with enhance the production rate with in minimum working hours.

The research focus on the real time monitoring of Inventory and actual material used in site for respective group of activities using BIM plugins. The protype development enables the comparison of planned quantification of material for activities, scheduled in Navisworks, using imported models from REVIT. Real time Inventory management allows managers for timely material procurement and better financial management. of project.

CHAPTER 2

Literature Review

2.1 BIM Definition:

At the present time, the architecture, engineering and construction (**AEC**) industry has evolve to provide analysis in separate dimensions. Each dimensional analysis provides information about the project time, project cost, activities schedule and work flow chart organization of any project.

Mankind and engineers have achieved creating designs, ensuring practicality with respective problems. Building Information and Modelling has allowed simulation of virtual design and integration of constructional activities involving time cost and other dimension improving work rate of any project. This technology enables any client to easily extract relevant data assuring oneself from exact details of project.

Numerous present-day models are outlined on BIM and they are effectively compiled on BIM. Many projects are organized and their attributes are carried out using BIM. Each aspect is categorized to specific layer. The layers are 2D and 3D (M. Subhi and Dr. R. N. Uma 2018). Each layer provides graphical representation of respective project models and its component. BIM illustrate them numerically and graphically with perfect information.

BIM or Building Information Modelling is technique that allows creation of information on construction project and manage the created information through project life cycle. The output model built provides detailed information of each key aspect and can be updated at

respective stage. of the project A digital Building Information Model enriches construction information, enable optimization of managerial actions, resulting in a perfect project life cycle.

Any project life cycle requires proper information flow. Its requires pondering over each specific problem. Building Information Modelling (BIM) new informative and technological tool that is used to visualize 3D topographical features of site and assist in production of project life cycle plan(Xu, Ma et al. 2014). Actual information flow through such tools indicates items such as the materials (components) quantification, cost estimation, defining risks, safety of material and labors.

Building Information Modelling (BIM), is combination of tools that has immensly enhanced the Architecture, Engineering, and Construction (AEC) industry(Moreno, Olbina et al. 2019). Researchers have covered every aspect of AEC industry. BIM act as tool for development and revolutionization of construction industry. BIM allows individuals, private and government firms to have better planning, designing, construction, operation and maintenance of buildings and diverse physical infrastructures, such as roads, railways, bridges, ports and tunnels(Moreno, Olbina et al. 2019). BIM basically provide virtual life-cycle of certain project(Li, Wang et al. 2014). Following Figure 2.1 explains BIM managing the complete project life cycle. The diagrams show all the task executed under BIM in each phase of construction

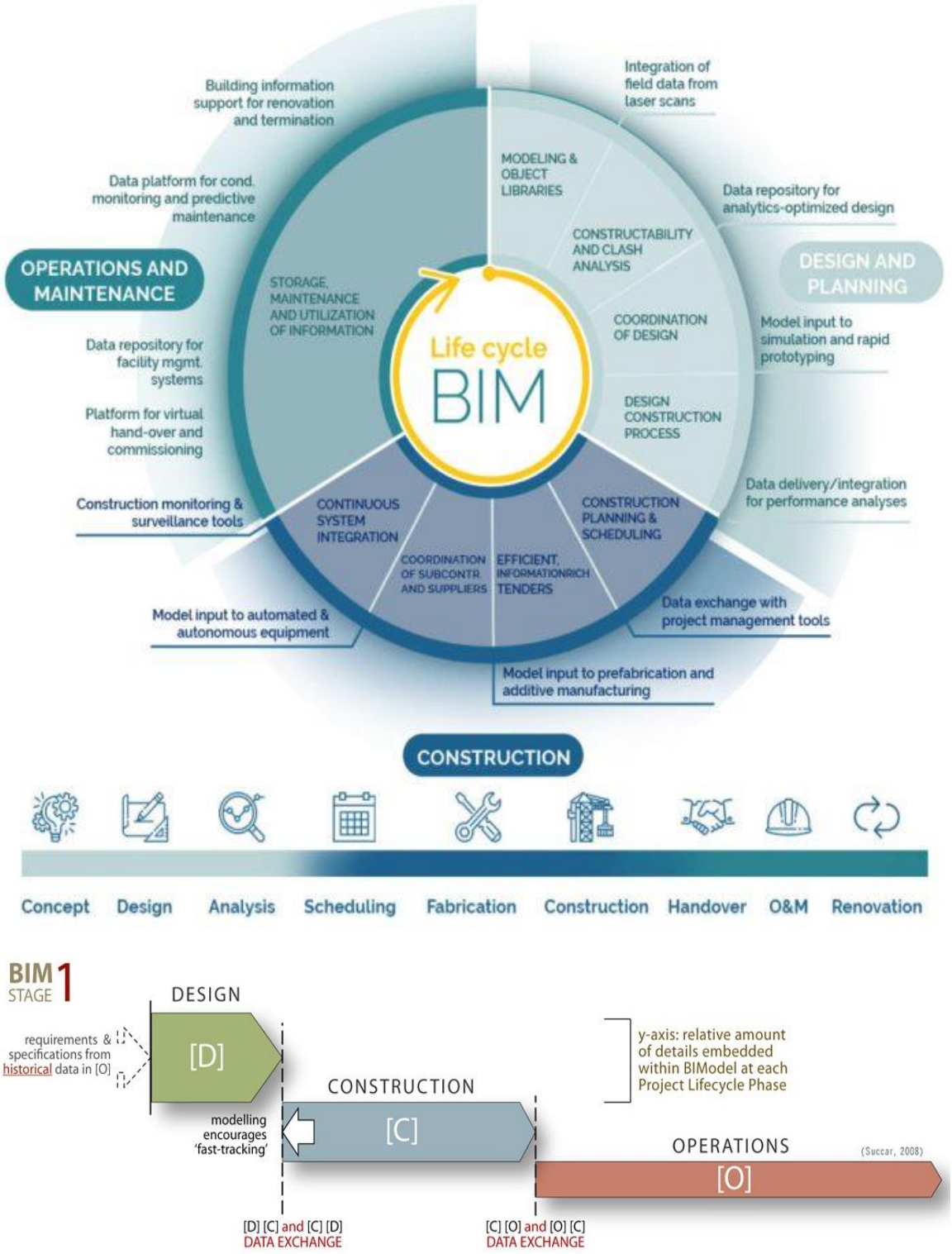


Figure 2.1 BIM in Project Life Cycle

2.2 Benefits of BIM

BIM is an ideal and most beneficial, modern tool for modelling and design. Contrary to Traditional Auto Cad designs and illustration, BIM is more economical and reduce time of designing phase(M. Subhi and Dr. R. N. Uma 2018).

Previous researches has indicated the involvement of BIM in different project areas(Moreno, Olbina et al. 2019). Many tools have been developed to manage the material quantification. Construction material management is inner core of every small or large project. The static 3D model, not only provide virtual image of site area but it links material requirement for each schedule activity(Li, Hou et al. 2014). The research indicates the feasible technological methods for management of project cost and wastes. It shows BIM is beneficial for in building construction resource management and real- time cost controls but its limits it approaches towards inventory management and material tracking on site. BIM benefits in the Construction Industry are highlighted in the Figure.2.2

Figure 2.2 BIM Benefits in Construction

2.2.1 Preconstruction Benefits to Owner

An owner invest his money, so he needs to ensure the completion of project on time. Owner need to be aware of whole project. He must know the timely scheduling and financial achievability of project. BIM is the unique tool that provide a database that enables owner to check the whole plan and design of project, budget needed for its execution, any anticipated error in project that owner needs to remove or use any alternative measure. All such elaboration is associated with visualized model to assist the owner. (Reddy, 2019). Figure 2.3 shows Top five BIM benefits in Pre-Construction phase which are explained further

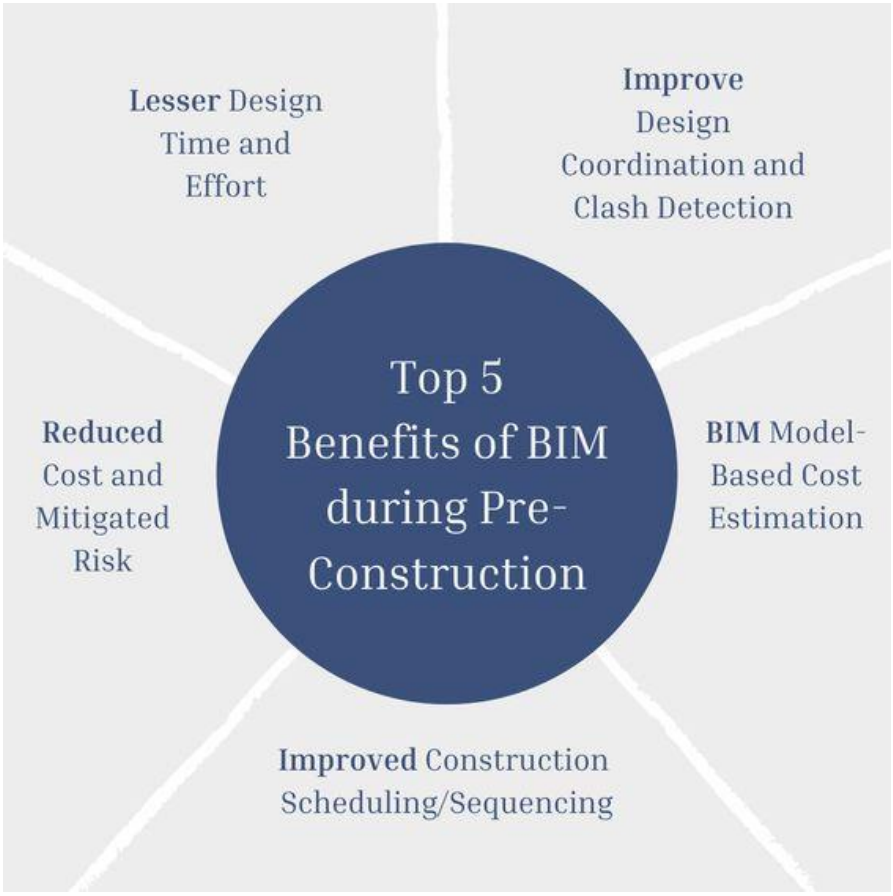


Figure 2.3 BIM Pre-Construction Benefits

2.2.1.1 Increased Building Performance and Quality

Proper modelling and design increase building performance and quality. Design includes building architectural design, building structural design, schedule execution, quantity ratios, cost estimation. Design change with respect to time and situation on site. BIM enhances the design performance and creditability. Traditional methods and software provide design but lacks assistance in error removal. (Kulkarni & Mhetar, 2017).

2.2.1.2 Economic Sustainability

In traditional methods and software, 2D architectural drawing are managed separately while structural drawing are created discretely. It requires more time as well as enhance financial burden. BIM offers working on multiple models by giving all possible drawing, at any time, in possible manner. BIM improve the energy efficiency and economical sustainability. (Reddy, 2019).

2.2.2 Design Benefits

BIM 2D and 3D model presents site projections, spatially represented in x, y and z plane in partial or complete transparency. The process flow with the development of 2 Dimensional drawings (2D) into digital model based on 3 Dimensional view (3D), and associate time of work flow (4D) and cost (5D)(Kamaruzzaman, Lee et al. 2016). Such model facilitate initial cost estimation process. The integrated BIM plugins for cost estimation enhance quantification process and create bill of quantity for respective objects in few seconds(Plebankiewicz, Zima et al. 2015).

Figure 2.4 is highlighting the BIM Dimensions and the main task performed under action of respective Dimensional policies. All the requisites of specific Dimensions are bulleted in given diagram.

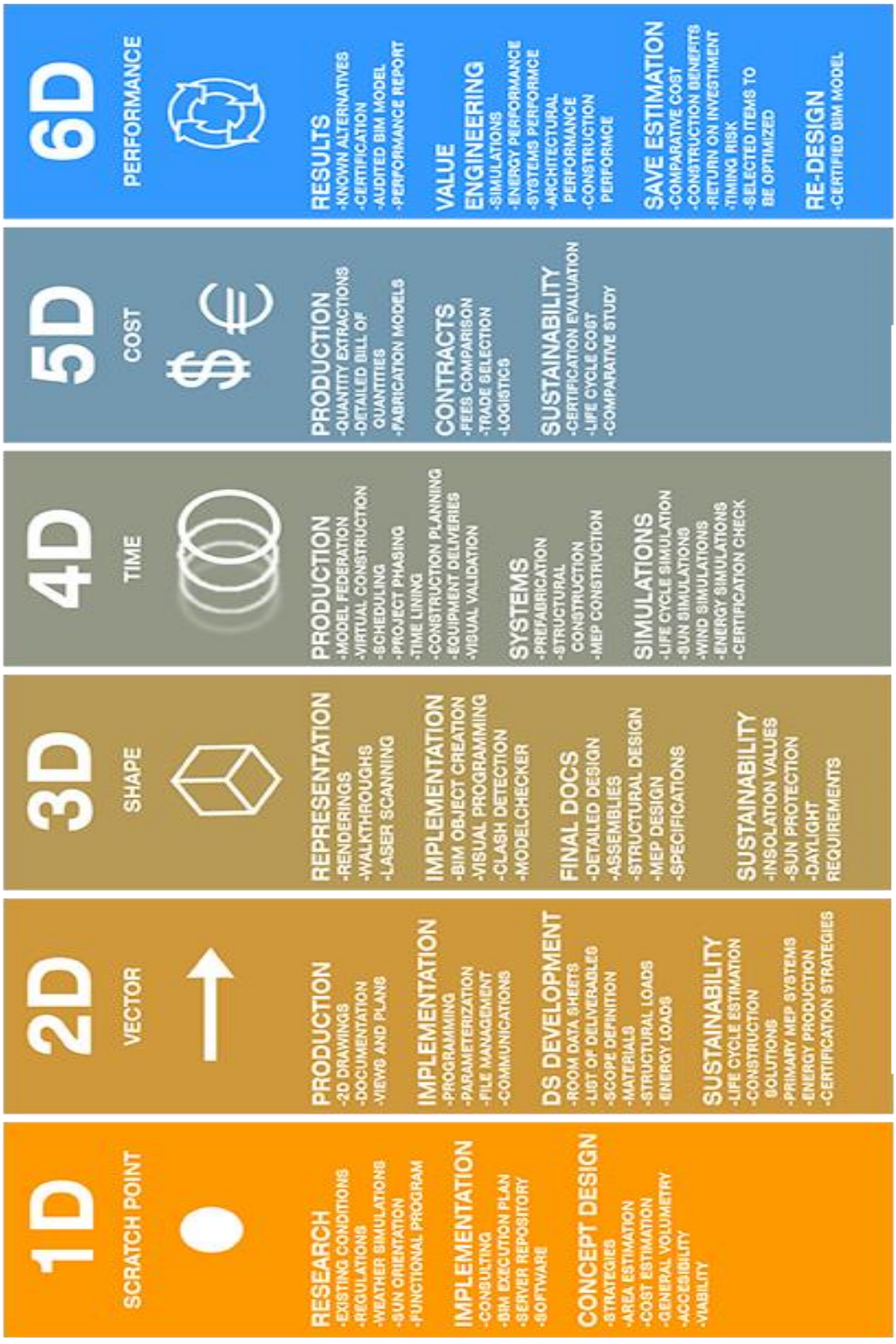


Figure 2.4 BIM Dimensions

2.2.2.1 Accurate Visualizations of a Design

AutoCAD drawings design are 2D and 3D representation of model but BIM ensures more comprehensive design. Its provides accurate layering of model, connecting it to others aspect of project. Its make design more complete and better visualization can have mere effect on owner or worker understanding of project. Therefore, collective use of BIM is ensured(M. Subhi and Dr. R. N. Uma 2018).

2.2.2.2 Automatic Low-Level Corrections

Detailed observation and analysis of 3D model in different perspectives is carried out. Lower level correction is design can be automatically rectified I using BIM to create perfect and design. All changes in design done manually using traditional methods, will be automatically completed keeping genuity of project designs.

2.2.2.3 Generation of Accurate 2D Drawings at Any Stage of the Design

2D drawing are bridge between worker and engineering. Its constant rechecking is as much necessary as its accuracy. Traditional methods and software's like AutoCAD do not provide this perspective. BIM provides you the option for 2D drawing generation at any stage and correcting it if required(M. Subhi and Dr. R. N. Uma 2018).

2..2.2.3 BIM 4D Simulation

BIM 4D simulation represent the 3 Dimension model of object with respect to time. It schedule each part of project 3D model to time restrain. 4D simulation helps project

management team to coordinate and systemize their work flow. BIM software can be used for 4D simulation process(M. Subhi and Dr. R. N. Uma 2018).

It plays vital role in safety management analyzing time based risks. It improves various construction strategies to meet delivery date. Decision making process is assisted by virtual execution of project during planning phase. Time based clash detection and project delays detection tools are provided(M.Dadashi Hajia, H.Taghaddos et al. 2021).

2.2.2.3 5D BIM Cost Estimation

Cost estimation is categorized as 5D BIM after time as it changes with time(M. Subhi and Dr. R. N. Uma 2018). Cost estimation is vital for any project as it predict the total cost of resources and labors. 5D in BIM uses 3D model integrated with time scheduling and provide the predicted financial value(Chowdary and Amin 2016). It is significant for decision making process in planning phase. It play effective role business unit decision and provide base for source funding units.(Kamaruzzaman, Lee et al. 2016)

2.2.2.4 Earlier Collaboration of Multiple Design Disciplines

BIM facilitate the prior association of multiple design discipline. Structural and architectural design can be collaborated mutually at same time. Lets say that 2D architectural plan and 3D visualization models of any house provided by architectural engineers are used to provide structural model of that house. Also allowing project manager to schedule the project activities and estimate project cost.

2.2.2.5 Extraction of Cost Estimates during the Design Stage

Timely value of money is core of any project. Material procurement and preordering is necessary for timely execution of project. BIM provide the tool for estimation of cost in design phase of project. Extraction of cost estimate enable comprehensive understanding of project worth. In order to understand this statement, let a take the example of construction of building superstructure, analyzing its material and their ratio will enable managers to extract a cost estimate, to order needed material and labor for respective activities. Cost estimation helps to decide future of the project.

2.2.3 Post Construction Benefits

BIM is not just a software. It is whole database for each specific project. BIM modernize the AEC industry by making amendment in any project in a standard way. It assists in better management and operation of inventories and facilities

2.2.3.1 Better Management and Operation of Facilities

BIM technology identifies the facilities as key factor of project. Better facilities management and operation gets the best out of design. The design is systematic process to get work done in a continuous manner. BIM technology provides quick, acute and accurate outputs without any hurdles.

2.2.3.2 Integration with Facility Operation and Management Systems:

A management system gives better credible infrastructure to people and company around. BIM has this function to give and it also provides many facility operations throughout the

world. It gives enough information about the project that is required and it makes things feasible and being at the role of site engineering you can come up with productive results by all means necessary (EUBIM Task Group, 2016).

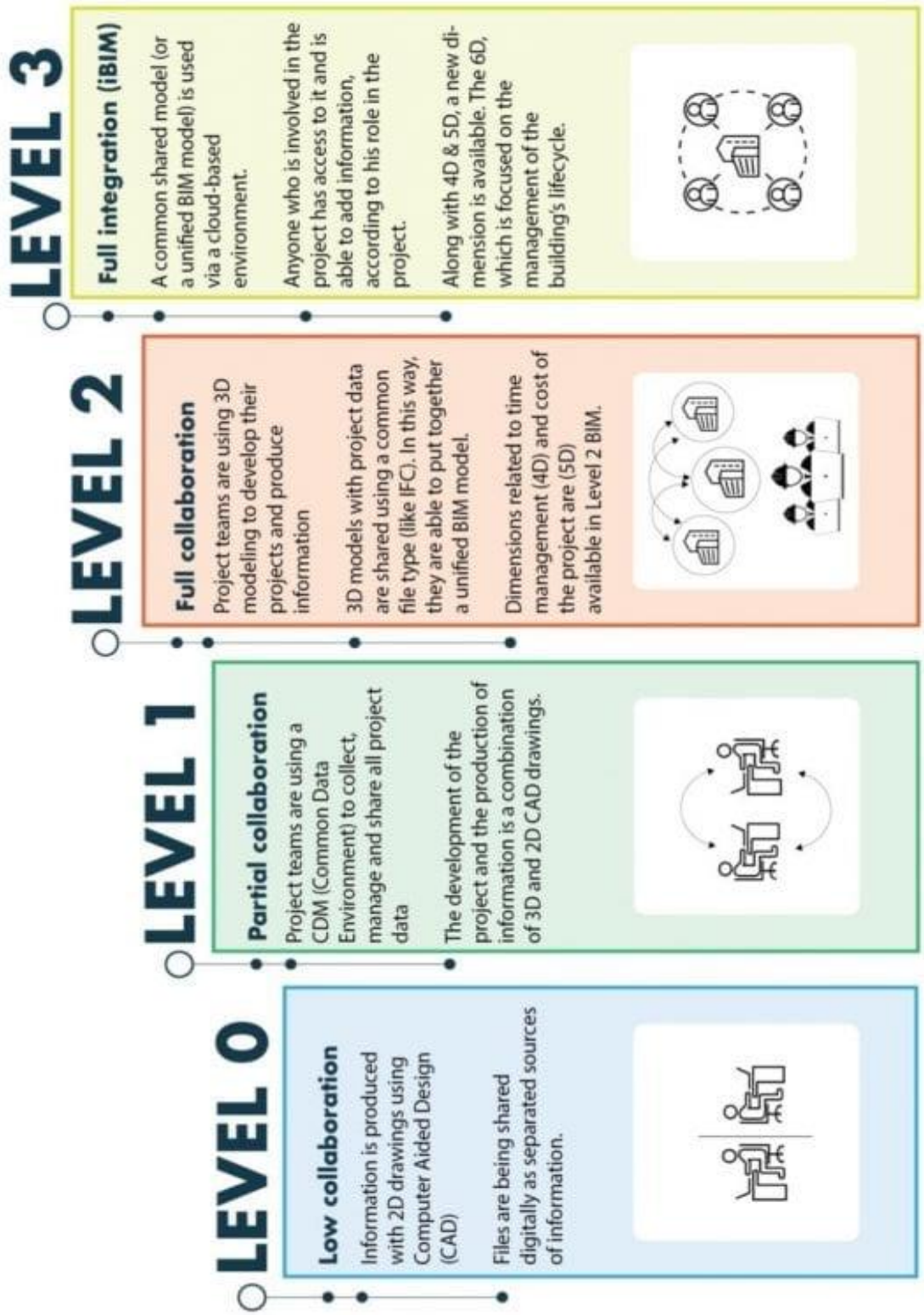
BIM is vital for ongoing construction sites. There are many problems that can be solved by stakeholders that can cause serious problems. For example, scheduling of activities can be planned to avoid procrastination of work. Mathematical problems in material input and cost estimation can be avoided. Many interrelated inputs like measure of material with its ratios and aftermath can be rectified by BIM. Financial prospective of project is necessary factor of design. The design must attain financial data using financial measure related to material input. BIM enables all the practical means to obtained financial record at any time.

2.3 Maturity Levels of BIM

BIM maturity model enables construction stakeholders to control and process the information exchanged. BIM maturity assessment provide definition of implemented steps and recognition of remaining activities. The prerequisites are BIM steps that's are used for recognition of essential activities, services and materials. Different stages are defined that people could use for checking progress and precisions(Natalija Lepkova, Rana Maya et al. 2019).

The BIM maturity level and collaboration levels has been explained as shown in Fig 2.5. Collaboration of BIM Dimensions decide its maturity level. Level 0 show just vector representation. Level 1 maturity shows the integration of 2D and 3D respresentations. Level 2 allows collaboration of 4D and 5D BIM while Level 3 defines 6D BIM

Figure 2.5 BIM Maturity Levels



2.3.1 Level 0 Non Existent

The goals and objective is yet to be specified. Also the process is not unified into business aspect.(Alaghbandrad, April et al. 2015)

2.3.2 Level 1 (Initial)

At this level, goals and objectives are defined. The process is hectic and chaotic.(Alaghbandrad, April et al. 2015) It lacks active senior management support. BIM software tools are applied individually in part of activities and have much lesser collaboration(M.Dadashi Hajia, H.Taghaddos et al. 2021).

2.3.3 Leve 2 (Defined)

At this level, organization look after the process according to standard organization guidelines(Alaghbandrad, April et al. 2015).Senior management of project authorize the policies and process the operation of data utilizing BIM management system. Basic BIM guideline are provided in all perspective as training instructions, workflow manuals etc. Interrelated parts of project collaborate under the standard policies and guidelines issued by authorities. Teamwork rate increase under mutual dataflow of BIM technology(M.Dadashi Hajia, H.Taghaddos et al. 2021).

2.3.4 Level 3 (Managed)

At this level, the process planning is complete and execution of is initiated utilization of skilled employed people and provided materialistic resources to produces controlled and

required results. The real time monitoring of relevant stakeholders is carried continuously in a controlled environment.(Alaghbandrad, April et al. 2015)

The employed staff become aware of BIM implementation. Marketing efforts are regulated under devised monitoring system. 2D representation and 3D models are analyzed. Quantification, illustration, activity scheduling, financial estimation and other analytical properties are managed through standards and quality plans. BIM managers are responsible for project alliance either short term or permanently.(M.Dadashi Hajia, H.Taghaddos et al. 2021)

2.3.5 Level 4 (Integrated)

At this level project management use statistical and quantitative techniques to ensure the performance of project. Project team work quality is monitored and any correlative action is done if needed. BIM technology and implementations are integrated in different field of project. All the activities of staff, throughout whole Work Break Down Structure (WBS), from lower level to managerial position, are economically managed. BIM software follows the main objective of the project and documentation is carried out systematically (M.Dadashi Hajia, H.Taghaddos et al. 2021).

2.3.6 Level 5 (Optimization)

At this level, technological improvement is carried out to meet quantitative and qualitative performance of project. Also, incremental and innovative improvement are done to look upon its business objectives(Alaghbandrad, April et al. 2015).

For better collaboration among project stakeholder, BIM implementation becomes universal at this level to monitor the strategies and action of stakeholder continuously. BIM software and technology has ability to adopt any change to strategic benchmarks. Contractual models modification is also carried out for all stake holders.(M.Dadashi Hajia, H.Taghaddos et al. 2021).

2.4 ABC Analysis

Better management system generates more revenue under lowest possible financial expenditure. Activity-Based Costing (ABC Analysis) is a technical system, practically adopted for managerial works like costing, budgeting and accounting(Ahmad Zeb, Daud Khan et al. 2017). ABC analysis is a technique that assist organize to achieve their goal. It allows management to monitor their resources and evaluate their costs on basis of worth to company(Rudolf Kampf, Silvia Lorincová et al. 2016).

Traditionally, the ABC analysis technique is defined by "annual dollar usage" criteria which limits to only homogeneous products.(Liu, Jiapeng Liao et al. 2016). ABC studies must be conducted to sustain the material tracking. Maintenance of necessary stock in inventory and protection of materials in an inventory to avoid inventory maintaining cost and to rectify the stock taking problems. (Liu, Jiapeng Liao et al. 2016).

ABC analysis categorize inventory items based on the items' consumption values. This is the process of an "material classification process" which classify the materials into groups on the basis of its worth, A, B and C: "A" shows the "most expensive items in the materials" and "C" considers the "least worthen items", whereas "B" ranges in-between "A" and "C".

It emphasis on the critical few (A items) and not on the trivial many (C-items)(S.S.Mahagaonkar and A.A.Kelkar 2017).

Category A defines about 70% of total sale vale items. Category B occupies the 20% of total sales value items and category C allows about 10% of total sales value items(T. Phani Madhavi, Steve Varghese Mathew et al. 2013).

ABC analysis is advantageous in the material management. It aids rigid and improved controls of inventory, providing assistance in management of valued products. It increases the efficiency of inventory control over its impact on final outcome. Expenditure cost of inventory decreases adopting ABC analysis techniques(Shreesha.S , Sundip Shenoy R et al. 2016).

2.5 IOT Technology

2.5.1 BIM and IOT

The absence of an effective framework for data sharing has been a test in construction industry for a long time that restrains the turn of events, execution, and operational proficiency of cutting edge development techniques. (Wang, Altaf et al. 2020) presents an idea of an IoT-based shop floor material managing framework for a panelized construction organization.

Checking of unapproved interruption on building area is critical to lessening wellbeing mishaps. (Jin, Zhang et al. 2020) kept examination around the IOT-based procedures for constant identifying, finding, and disturbing of unapproved interruptions to risky working environments on the building site by using and incorporating the cutting edge data advancements like RFID innovation, thermal infrared sensor, Bluetooth module, cell phone, web, and cloud data computing.

The construction industry has quite possibly the most dangerous work spaces around the world, which represents around 1 in each 5-word related fatalities. The high pace of working environment causes wounds, fatalities to laborers and is postponements and extra undertaking costs. This examination which is persuaded by the improvement of such coordinated techniques and summing up late advancements of sensor-based wellbeing the board frameworks and progressions in security the executives through BIM. The exploration is distinguished and a blueprint for potential future examination is given. The aftereffects of the audit uncover the capability of consolidating sensor driven frameworks

with BIM for improving wellbeing the executives in development. (Asadzadeh, Arashpour et al. 2020)

2.5.2 Open Standards, BIM and Automation

(Dave, Buda et al. 2018) diagramed the endeavors to foster a stage that incorporates the fabricated climate data with IOT sensors in an environment, web-based framework considered Otaniemi3D that gives data about energy use, inhabitance and client solace by coordinating Building Information Models and IOT gadgets through open informing norms (O-MI and O-DF) and IFC models.

Fires in the high-rise can be a huge danger to tenants and firemen. The cutting-edge advances, for example, sensing-based Internet of Things (IoT), Building Information Modeling (BIM), Virtual Reality (VR) and Augmented Reality (AR) may offer incredible potential to improve building fire security. Be that as it may, the industry doesn't utilize the incorporation of advances up to full extent. The researchers have kept the examination around fostering a novel system as a proof of idea for situational mindfulness improvement by incorporating BIM advances. (Chen, Hou et al. 2021)

2.5.3 BIM and RFID

BIM and RFID both is used to enhance the supply chain and provide a better coordination on and off the field. To further improvise, researchers have put forward the idea of using the theory of lean which permits project members to consolidate details close term forecast with BIM and RFID advancements to more readily oversee material stream measures. (Chen, Adey et al. 2020)

As most recent advancements, calculations and cutting-edge confinement methods that can be used to fill in as Internet of Things correspondence convention via computerizing are RFID framework. Researchers (Alwadi, Gawanmeh et al. 2017) put forward the study for the most recent accessible exploration in Cloud Computing, stock administration middleware workers, and RFID Identification and confinement calculations that can be utilized to robotize a stock that has a latent RFID framework.

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2.6 Inventory Management

Despite the fact that progressions have been made in managing of activities because of the digitalization, the effective utilization of digital information is as yet missing for the coordination of the supply chain in the construction industry. So, researchers put forward a 4D Model that could modify orders according to varying demands using data-driven and schedule oriented supply chain. (Chen, García de Soto et al. 2021)

The procurement of the materials for the construction include difficulties identified with decreasing inventory, speeding conveyance, and expanding the control of materials, in this manner diminishing the general task cost. (Safa, Shahi et al. 2014) provided the idea for the improvement of the ICMM model for the effective acquisition of development materials, fundamentally using the TOPSIS technique as a viable system for the supplier preferred cycle. The created model is based on thought of most of the exercises related with the acquirement of materials.

As panelized construction is preferred, the requirement for an incorporated management measure is developing quickly. In such manner, (Hamdan, Barkokebas et al. 2015) suggested a system that integrate BIM strategies with reproduction to give inventory monitoring and the management instrument. This device can be used to diminish inventory cost and size to enhance the execution of the construction supply chain.

Construction firms have been focusing on the nature of approaching materials and the active items, yet they haven't been focusing on the expenses related with moving and storing them. (Lee and Billington 1992) portray 14 entanglements of supply chain and

some comparing openings. The more intricate your organization suppliers, producers, and distributers, the certain you can acquire operational proficiency by going to stock.

Lately, with the expanding level of rivalry in the worldwide construction industry, a few exploration endeavors have zeroed in on the use of information technology (IT) as an approach to enhance the joining cycle of construction supply chain management (CSCM). Visual portrayal of the cycle can give a compelling apparatus to checking assets in the CSCM. An incorporated BIM-GIS framework for envisioning the inventory network measure and the real status of materials through the supply chain is introduced by (Irizarry, Karan et al. 2013)

Researchers explained the concept of Offsite construction may include the movement of the tasks from construction site to manufacturing facilities which results in productivity but the practices like time studies cannot deal with the changes that happen from advancements in the productivity. So they provided a solution that would detect the progress by using deep algorithm with the existing CCTV footage.(Martinez, Barkokebas et al. 2021)

(Lin, Petzold et al. 2019) proposed a continuous 4D AR framework for modular construction monitoring. By utilizing an AR registration technique addressed by relative coordinate and a fixed monocular camera, BIM 3D information like shape, size and floor can be connected with building site effectively.

With regards to interior works, delays happen every now and then to the decided timetable. Since unsettling influences are unavoidable, a constantly securing of the construction workflow is fundamental. (Kropp, Koch et al. 2014) put forward the idea of a drywall

completion state assurance strategy under the utilization of image recognition, PC vision and AI is proposed. The strategy would manage the programmed discovery of the three unique states: introduced panels, plastering and painting.

(Min and Sui Pheng 2007) have pointed out the although JIT(Just in Time) model is preferred over the EOQ(Economic Order Quantity) but it is evident that the benefits that JIT are not adequate enough to shed light on the important aspects of inventory management such as the lack-of-stock costs and the effect of inventory policy on item quality and its manufactured flexibility. So they put forward the idea of JPTV (JIT purchasing threshold value) that would deal with shortcomings of both models EOQ and JIT.

(Kim, Cheng et al. 2015) have conducted an investigation that presents an orderly and viable methodology for dimensional and surface quality evaluation of pre-cast concrete components utilizing building information Modeling (BIM) and 3D laser checking innovation. The process consists of the inspection checklists, procedure, the selection of a scanner and the data storage. The structure is inspected by surveying the dimensions and characteristics of real precast concrete panels utilizing a 3D laser scanner.

A construction site that is using a four-dimensional (4D) computer-aided design (CAD) model needs the data to be updated regularly for a precise workflow. However, the process is not automatic and may be time consuming, to overcome this problem, (Kim, Kim et al. 2013) presented the idea for an image processing based methodology for the automatic updating of a 4D CAD model. It would be having 3D CAD-based image mask filters, color-

based noise removal, and area-based progress calculation, the image processing approach provides as-built schedule information.

Proficient and compelling construction progress tracking is important to construction industry. Current manual tracking techniques are tedious and additionally mistake inclined. Three-dimensional (3D) laser scanners are still investigated but are too complicated for the data that is scanned on the field. The framework is portrayed thus as that it joins 3D element recognition technology with plan data into a consolidated 4D element arranged progress tracking system.(Turkan, Bosche et al. 2012)

(Paul, Sarker et al. 2014) have put forward the idea of dynamic planning process which will deal with short-term demand fluctuations between the supplier and retailer. The proposed model offers a possibly exceptionally valuable quantitative examination to help managers to settle on immediate and exact choices on the plan, at whatever point an abrupt or a progression of interest variances happen in an inventory network framework. The model can be expanded for any production network, assembling or administration industry to oversee the dangers of interest variance with a blemished production.

Following is the table of synthesized prominent researches about their studies in Inventory Management, IOT and BIM as shown in table 2.1

TABLE 2.1 . Following is the literature review of prominent researcher about their study in Inventory management ,BIM,IOT and construction supply chain management

Sr	Main Theme	Focus	Methodology	Major Findings	Citations
1	BIM-based government procurement system- the likely development in Taiwan System.	Procurement system.	Case study.	Assessment of the achievability and the way to dispatch a BIM based procurement framework for general works in Taiwan.	I
2	A framework for integrating BIM and IOT through open standards	Environment data with internet of things (IOT)	Prototype Development	Provides a framework incorporating IOT, BIM and Otaniemi3D, that would monitor about energy use, inhabitance and client solace in a campus-wide environment.	II
3	An E-Commerce Platform for Industrialized Construction procurement based on BIM and linked data.	E Commerce procurement.	Case Study.	Suggested BIM and connected information based online business stage for ICP is a novel coordinated data stage giving an answer for the mix of online business data in the construction.	III
4	Material delivery problem in construction project: a possible solution.	Material tracking approach.	Qualitative study.	A shipment tracking base methodology is proposed to give inventory transparency and a favorable to dynamic conveyance approach for effective material conveyances	IV
5	Cost control technique using building information modelling (BIM) for a residential building.	Cost control using BIM	Case study	Cost control is especially useful with BIM than a customary strategy all through the venture cycle	V
6	Improving cost ad time control in construction using building information model(BIM) A Review	Cost and time control using BIM	Review paper	The majority of the reasons for deferral and cost overwhelm are project worker's obligation, specialist's duty, proprietor's duty and outside factors. The utilization of BIM in the administration of development projects has extraordinary effect cost and time	VI
7	5D building information modeling – a practicability review	Cost and time control using BIM	Pilot study	5D BIM certainly has high level practicability which further differentiates BIM from Computer Aided Design(CAD)	VII
8	Cloud competing to enhance collaboration, coordination and communication in the construction industry	BIM application comparative to CAD	Conceptual framework using BIM on the cloud	In construction industry, the current trend is toward deploying BIM on the cloud in order to efficiently integrate and manage engineering information which is also termed as ubiquitous computing	VIII
9	Building information modeling based time and cost planning in construction projects	Technological progress using BIM	Case study	The use of modern software that allows BIM in construction projects represents a technological progress with advantages for all participants	IX

10	Cost and time control of construction projects: inhibiting factors and mitigating measures in practice	Cost and time control using BIM	Qualitative study	Top five factors inhibiting time and cost control are risks and uncertainties, inaccurate evaluation, complexity of project, non-performance of sub-contractors and design changes	X
11	Research on the application of BIM technology in the project management of Hospital construction	Time control using BIM	Case study	BIM helps in contradicting time and reduce the possible changes that shorten the project duration	XI
12	Building information model supply chain integration: A review	Lean construction using BIM	Review paper	Adoption of BIM in construction sector may be useful to adopt integrated project delivery in supply chain partner integration towards IPD/lean construction approach	XII
13	BIM- based construction information management framework for site information management	Site information management using BIM	BIM- based construction information database system	The continual approach ad management of construction information will allow for corporate level accumulation of knowledge as opposed to that individual accumulation of know-how	XIII
14	A BIM-based framework for material logistics planning	Material Logistics Planning Using BIM	Develop Framework for material logistics	This study enables sub-contractor to foresee the adverse effect of the material delay on the material logistics of site and improves coordination between supplier and contractor.	XIV
15	Construction supply chain coordination Leveraging 4D BIM and GIS integration	Cost Minimization Using BIM	Framework formulation	This study integrates framework to minimize costs in construction supply chains by generating optimized solutions for selecting supplier sites, determining the number of deliveries and allocating consolidation centers.	XV
16	A BIM-VMS integrated decision support tool for supply chain management in construction	Supply Chain Management Using BIM	Framework formulation to integrate BIM & WMS	Developed BIM-VMS plug-in can serve as a supporting toll for planning and decision making in logistics and supply chain management. Different materials or same material from different sources can be easily compared using the developed plug-in.	XVI
17	Generating construction schedules through automatic data extraction using BIM (building information modeling technology)	Automated schedule Generation Using BIM	BIM Analysis	Using the extracted information, the proposed system creates construction tasks, computes activity durations using available activity production rates, applies sequencing rules and finally outputs a schedule.	XVII
18	Integration of cost and Schedule using BIM	5D Model with Time & Cost Integration Using BIM	BIM Analysis	This research proposes a model to link cost and schedule data, automatically following their linkage to BIM elements. First, the relationship between schedule activities.	XVIII

19	Implementation Method of Construction Schedule Management for Metro Engineering based on BIM modeling.	Construction Schedule Management Using BIM	Model development based on case study	This study proposed BIM-based modeling technology, with which a qualified BIM model used for BIM-based construction schedule management of metro engineering: also, key modeling technologies were utilized to improve modeling accuracy, modeling efficiency and model utilization.	XIX
20	Research on construction Schedule Management based on BIM	Construction Schedule Management Using BIM	BIM analysis	The use of radio frequency identification (RFID) technology in construction projects can facilitate the management of material entry, construction schedule control and operation and maintenance management.	XX
21	Cloud-based Materials Tracking system prototype Integrated with Radio Frequency Identification Tagging Technology	Materials Tracking System Prototype	RFID Tagging Technology	A cost-effective material management system based on a cloud - computing service integrated with Radio frequency Identification RFID for automated tracking was proposed. This study was only applicable for MEP fabricated items.	XXI
22	Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective	BIM-based-E-Procurement	Pilot Case Study	The BIM-based e-procurement prototype has been developed using distinct existing electronics solutions and an IFC server and was tested in a pilot case study, which supported further discussions of the results of research.	XXII

Key:

I = (Liu and Hsieh 2011); II= (Dave, Buda et al. 2018); III = (He, Li et al. 2018); IV = (Ala-Risku and Kärkkäinen 2006);

V = (Kulkarni, Mhetar et al. 2017); VI = (Tahir, Haron et al. 2018); VII = (Lee, Tsong et al. 2016); VIII = (Amarnath, et al. 2011);

IX = (Pučko, Šuman et al. 2014); X = (Olawale, Sun et al. 2010); XI = (Levy 2018); XII = (Khalfan, Khan et al. 2015);

XIII = (Lee, Park et al. 2018); XIV = (Cheng and Kumar 2015); XV = (Deng and Cheng 2016); XVI = (Chen and Nguyen 2019);

XVII = (Kim, Anderson et al. 2013);XVIII = (Fan, Wu et al. 2015); XIX = (Shi and Ouyang 2017); XX = (Li, Xu et al. 2017);

XXI = (Ko, Azambuja et al. 2016); XXII = (Grilo and Jardim-Goncalves 2011)

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

The research methodology adopted to achieve this study's objectives is discussed and presented in this Chapter. .Firstly, IOT based weight sensors prototype was developed. Followed by BIM based inventory management plugin was developed using C# programming language in Navisworks API and evaluated the functionality of the plugin by industry experts was carried out.

3.2 Software Used

Following are the software used for developing the prototype as shown in fig 3.1.

PARAMETERS	SOFTWARE
BIM PLATFORM	AUTODESK REVIT 2017 AUTODESK NAVISWORK 2017
Integrated Development Environment	Microsft Visual Studio 2019
Main programming language	C#
Graphical user Interface	Windows Form
Data base Configuartion	SQLITE
Sensors network programming langauge	Arduino

Figure3.1 Software Used

3.3 Research Design

The research design of our prototype is shown in fig 3.2

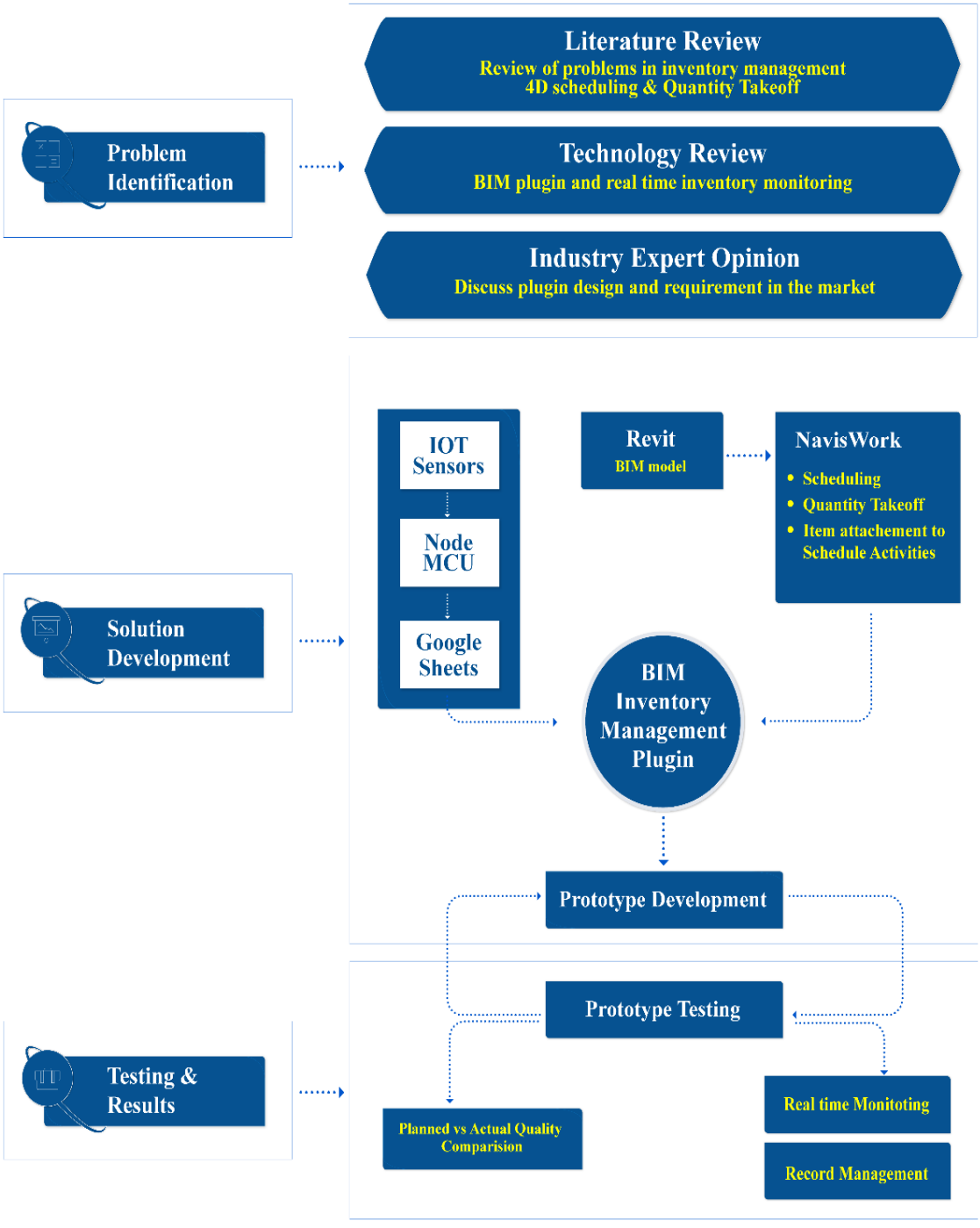


Figure 3.2 Research Design

3.4. IOT Based Weight Sensors

Introduction

The prototype is mainly divided into two parts, one is the IoT platform that measures the precise weight of material in field, calculate its volume in accordance with its density and then upload it to the cloud in real-time. The second part is a plug-in integrated in Autodesk Navisworks Software that performs further calculations according to the schedule and provide user with valuable information about the inventory. We are going to discuss the first part “The IoT System” that is composed of electrical components (Sensors, Microcontroller etc) responsible for providing quantitative data. We’ll discuss it’s key components, how it works, what are it’s pros and cons and what are the limitations that can be improved in further researches.

Key Components:

1- Load Sensors
2- HX711 Amplifier
3- NodeMCU
4- Cloud
5- Medium Density Fiberboard (MDF) Sheet as a base
6- 4 Sensor Holders to keep sensors in place

Following is the schematic diagram of sensor networks installed under the protype in order to measure weight shown in fig 3.3

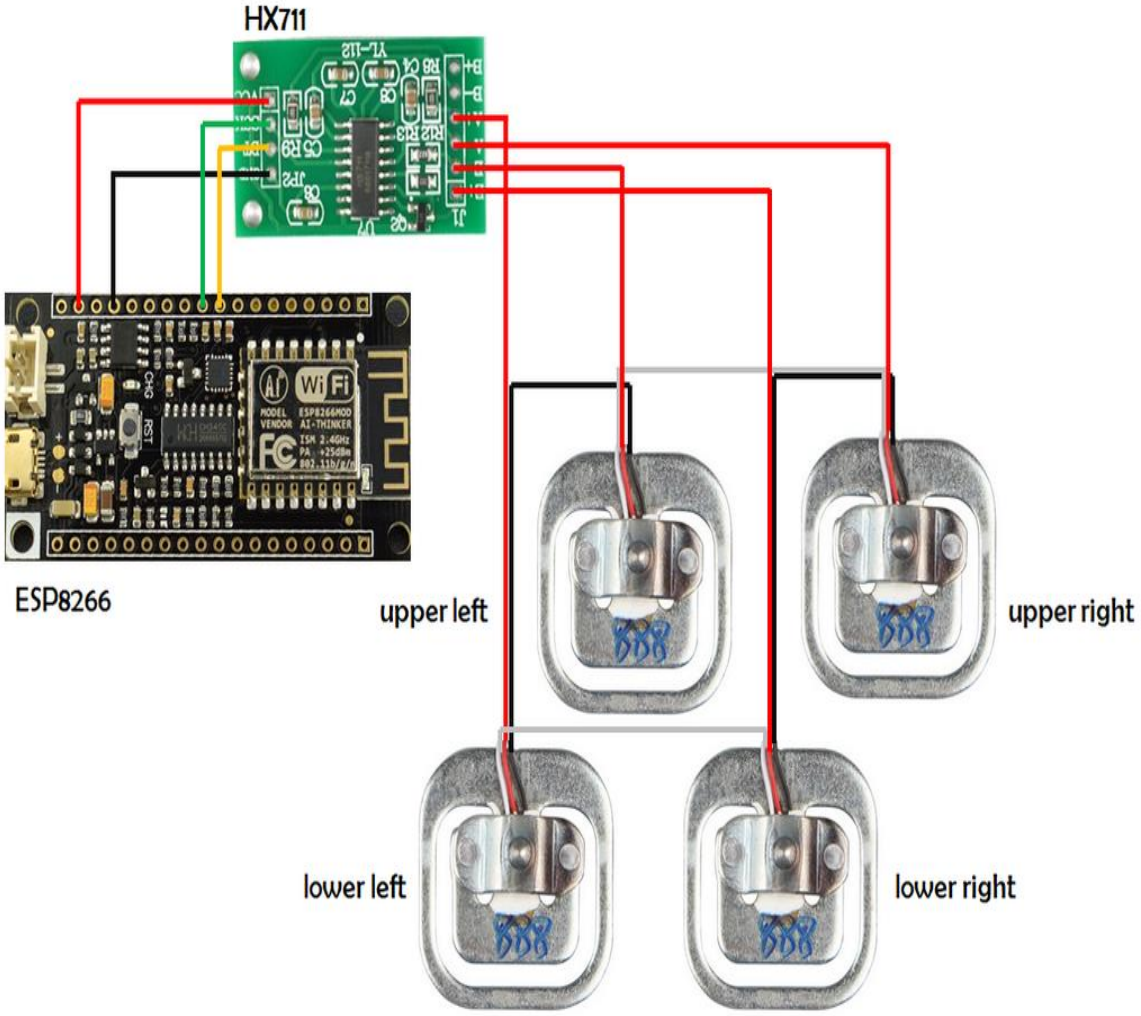


Figure 3.3 Schematic Diagram of Sensors Network

Wheatstone bridge layouts are commonly used for weight sensors .as shown in Fig 3.4

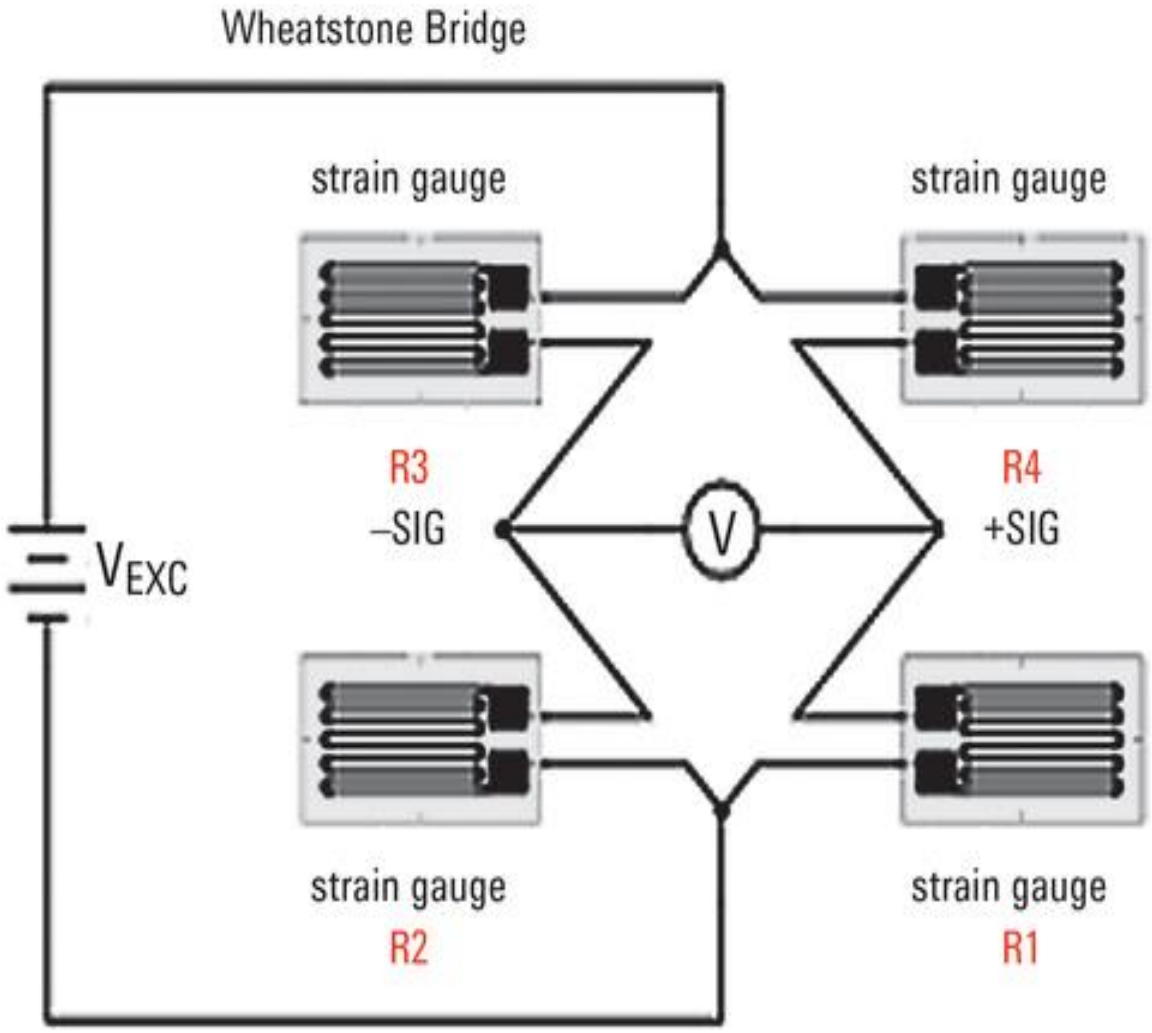


Fig 3.4 Circuit Layout

1. HX711 Amplifier

The Load Cell Amplifier is a compact breakout board for the HX711 IC that makes reading load cells for weight measurement simple. You can read variations in the resistance of the load cell by connecting the amplifier to your microcontroller, and with minor calibration, you can get pretty accurate weight measurements. This is useful for industrial scale, process control, or basic presence detection.

The HX711 communicates through a two-wire interface (Clock and Data). The GPIO ports on any microcontroller should work, and various libraries have been built to make reading data from the HX711 simple. The primary goal of this module is to amplify signals with very low amplitudes in order to achieve maximum accuracy.

2. NodeMCU

The NodeMCU (Node MicroController Unit) is an open-source software and hardware development environment based on the ESP8266, a low-cost System-on-a-Chip. The Espressif Systems ESP8266 features all of the essential components of a computer, including a CPU, RAM, networking (WiFi), and even a current operating system and SDK. As a result, it's a right match for a variety of Internet of Things (IoT) projects.

In a nutshell, NodeMCU is the brain of our IoT system, where all calculations are performed on sensor data and then the data is transferred to the cloud after accurate computations. We programmed this free source module using the Arduino IDE, which is a software that allows you to write code/sketches for several open source boards such as the Arduino uno, Arduino nano, ESP-32, and STM32.

3. Cloud

The cloud is a network of computer system resources, particularly data storage and computational power, that is managed by the user without their direct involvement. The terminology refers to data centers that are accessible via the Internet to a large number of people.

In our scenario, Google Sheets fulfils the cloud need. It's a spreadsheet tool that comes as part of Google's free, web-based Google Docs suite. Google Docs, Google Slides, Google Drawings, Google Forms, Google Sites, and Google Keep are all part of the service. Google Sheets is accessible as a web application, a mobile app for Android and iOS, a desktop application for Google's Chrome OS, and a BlackBerry app. Microsoft Excel file formats are supported by the programe. People can create and modify files online while collaborating in real time with other users.

We've linked a Google Sheet to our NodeMCU board so that we can get real-time readings from our system from anywhere in the world. Every minute, the data is updated and recorded on a Google Sheet with the date and time.

4. Project Working principle

First of all we have to do calibration of our prototype after that we will power up the system than we will place known weight on the platform to find the calibration factor. In this prototype we have used Arduino IDE software to control the process. The weight sensors senses the wight and transfer the electrical voltage to load amplifier. This amplifiers

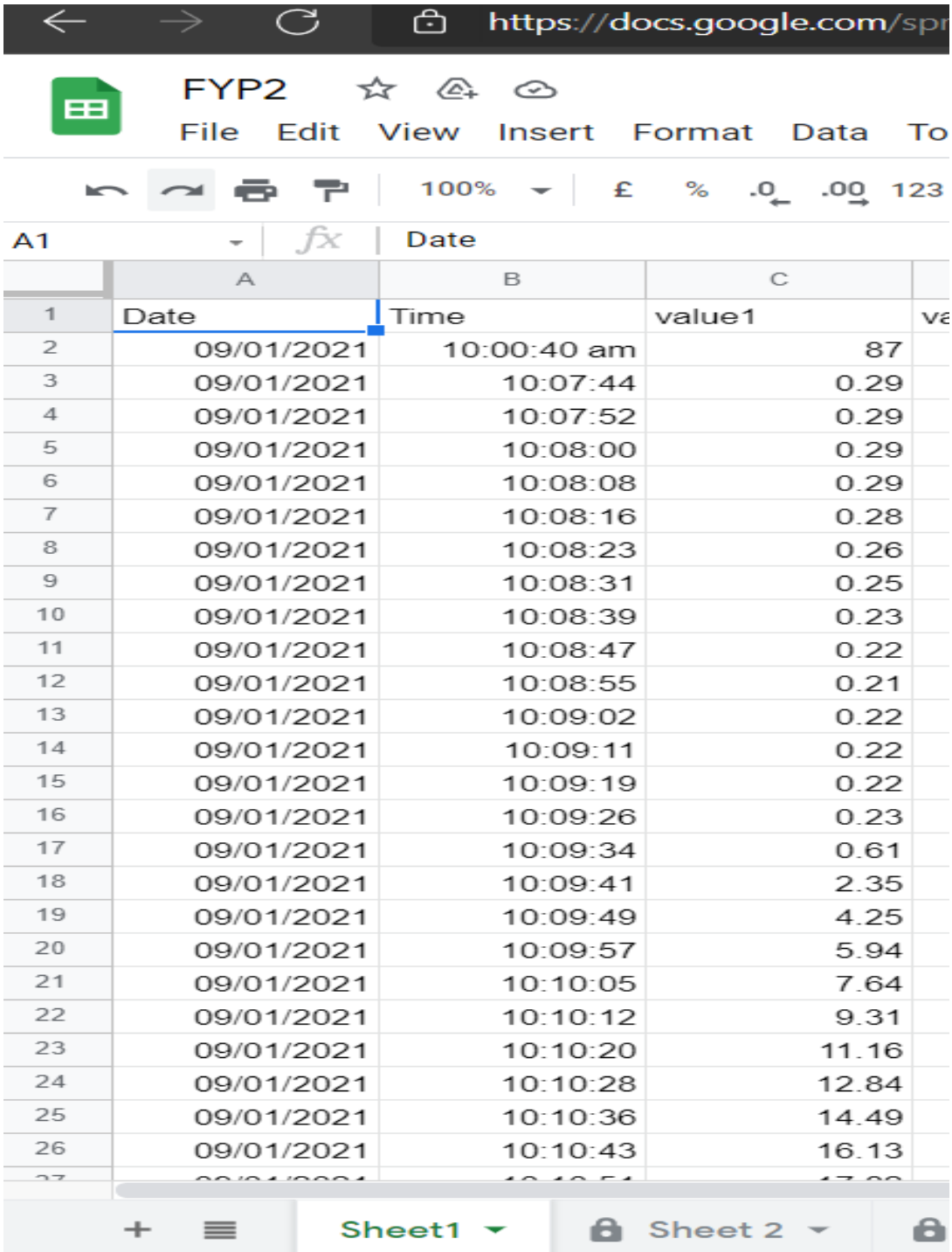
amplifies the signal so that signal could be easily read by nodeMCU, nodeMCU is a wifi based IOT chip and send the real time weight values to our cloud google sheets.

5. Arduino Code & Assembling

Following is design algorithm in Arduino software for sensors as hown in Fig 3.5

Figure 3.5 Arduino algorithm

The values are appearing in google sheet as shown in Fig 3.6



	A	B	C
1	Date	Time	value1
2	09/01/2021	10:00:40 am	87
3	09/01/2021	10:07:44	0.29
4	09/01/2021	10:07:52	0.29
5	09/01/2021	10:08:00	0.29
6	09/01/2021	10:08:08	0.29
7	09/01/2021	10:08:16	0.28
8	09/01/2021	10:08:23	0.26
9	09/01/2021	10:08:31	0.25
10	09/01/2021	10:08:39	0.23
11	09/01/2021	10:08:47	0.22
12	09/01/2021	10:08:55	0.21
13	09/01/2021	10:09:02	0.22
14	09/01/2021	10:09:11	0.22
15	09/01/2021	10:09:19	0.22
16	09/01/2021	10:09:26	0.23
17	09/01/2021	10:09:34	0.61
18	09/01/2021	10:09:41	2.35
19	09/01/2021	10:09:49	4.25
20	09/01/2021	10:09:57	5.94
21	09/01/2021	10:10:05	7.64
22	09/01/2021	10:10:12	9.31
23	09/01/2021	10:10:20	11.16
24	09/01/2021	10:10:28	12.84
25	09/01/2021	10:10:36	14.49
26	09/01/2021	10:10:43	16.13

Figure 3.6 Google Sheet Data

6. Calibration

First we put known weight i.e 15kg of weight on the wooden platform to check the calibration. Data is been transferred to the google sheet , however after achieving the required load, we unload the known weight, if the value come to zero this mean there is no error, if the values varies from zero ,subsequently values will be added or subtracted from the unknown weights of material.

In our case, it gives an approximately +500 gram of error. So for every unknown values, we add 500 gram to it to acquire accurate information of real time data.

7. Sensor Limitations & Environmental workability:

One of the basic Field is the limitations and working conditions for sensors embed in the module. All the test were performed in favorable & recommended environment. In any un-favorable results of sensors may deviate that may cause to a inaccurate results Some of the following are :

- Capacity: 40-50kg
- Values may deviate due to slight changes in balance and electrical interferences.
- Platform Should be leveled
- No moisture contact with the load sensors

3.5 Development of BIM Inventory Monitor Plugin

3.5.1 BIM platform

As rapid advancement and development have been done in BIM and ICT for extensive reasons and objective, regarding AEC industry, with respect to sustainability, project control techniques and others. In our Autodesk Revit 2017 will be used for modelling of building, while Autodesk Navisworks will be used for scheduling, quantification and project. Autodesk Revit 2017 will be used for modelling of building, while Autodesk Navisworks will be used for scheduling, quantification and Plugin usage in the end which would be linked with BIM model. Our main concern is with Autodesk Navisworks as plugin would be integrated there which is our objective. Revit is used to build architectural, structural, MEP model which is then imported to Navisworks.

In Navisworks, scheduling is done with respect to the model elements, Activities are created compliant with planned start and end date of that Activity Model items/elements are linked with the activities created in scheduling tab. In the meantime, Quantity takeoff is done using quantification tab in Autodesk Navisworks which is then linked with the created activities which is called 4D in BIM.likewise,5D can also be done in done scheduling tab. There are many software in BIM which verily used for different purposes in AEC industry. As shown in Fig 3.7

3.5.2 Plugin Development

In the second phase, plugin was developed for inventory management in Autodesk Navisworks. A detail study was done to understand the procedure adopted about inventory management in construction industry. Semi structured interviews were held with industry experts in order to know about the discrepancies done in the site and what are there requirement in order to remove the gaps in monitoring of materials, BIM software API were studied and BIM inventory monitor plugin was developed. Most BIM software has an API that may be used to enhance it features. A commonly-used programming language (i.e. C#) was used to create the plugin using Microsoft Visual Studio using .NET frame work(.NET). the google sheet integration in plugin was done by Python. A data connection was made between Navisworks and SQLite server using the API of AUTODESK Navisworks. Navisworks 2017 has been chosen for the work because it provides better visual presentation and ease of connectivity of API with external sources.

PLUGIN design algorithm:

The plugin algorithm was done in C# language as shown in the figure. 3.8.

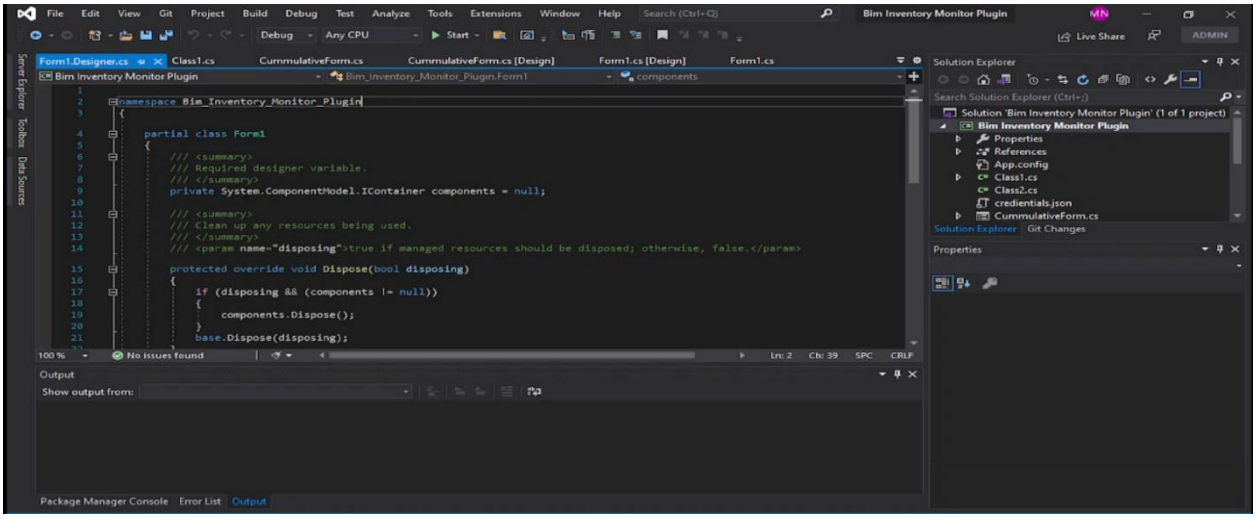


Figure 3.8 Plugin algorithm

Graphical user interface of the plugin

The GUI of the plugin is shown in Fig 3.9

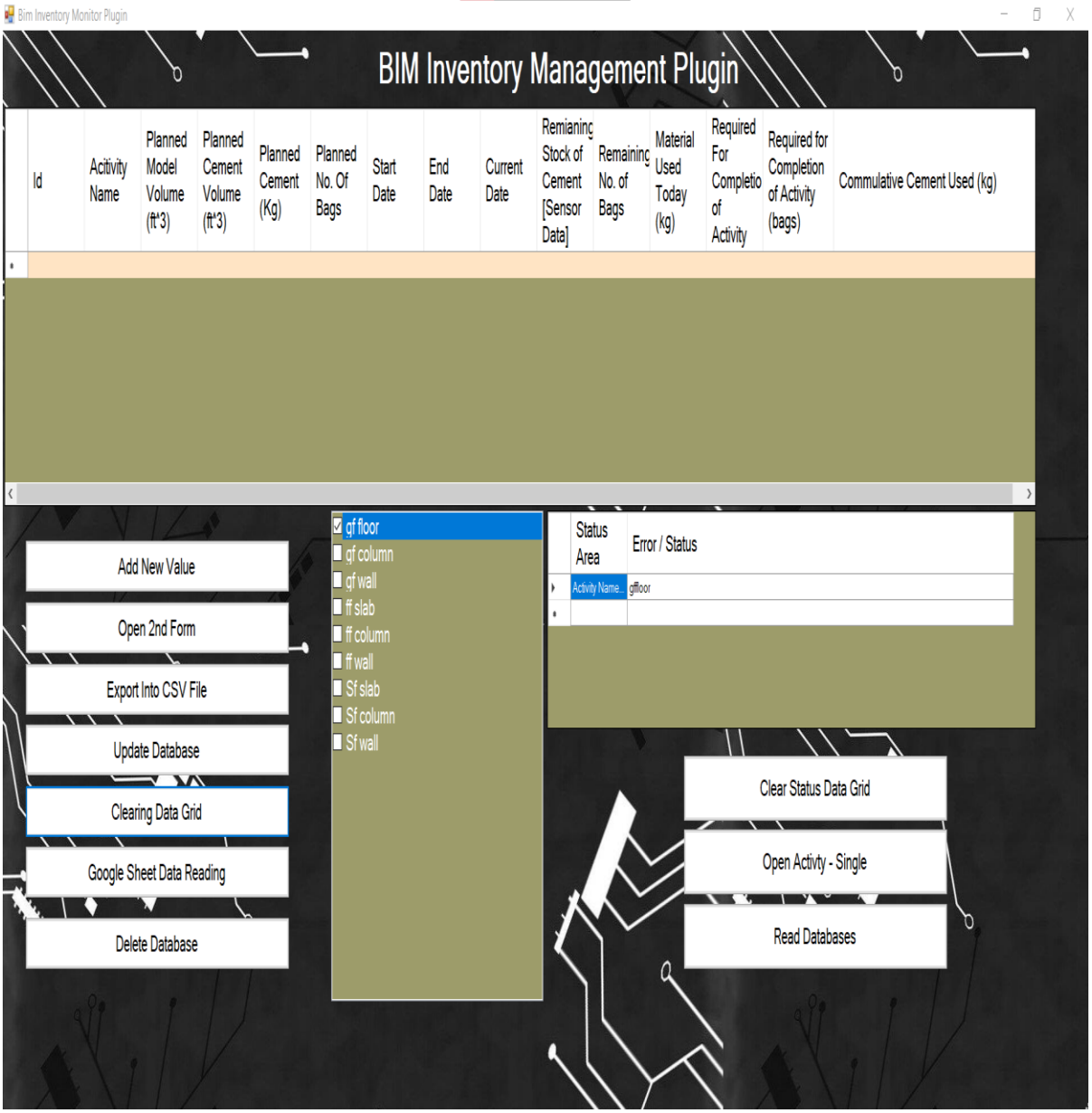


Figure 3.9 GUI of BIMP

3.6 Plugin evaluation and validation

In the last phase, the developed prototype was assessed to see how well it met the expectations for which it was created, as well as what areas may be improved.(paek 2001)**.**

As we have one unit of IOT sensors network, it only give value for one material i.e. cement.so our design model is reduced to its size as the capacity of unit sensors network is 200 kg as mentioned above. A random small sized BIM model was created in REVIT as shown in Fig 3.10….

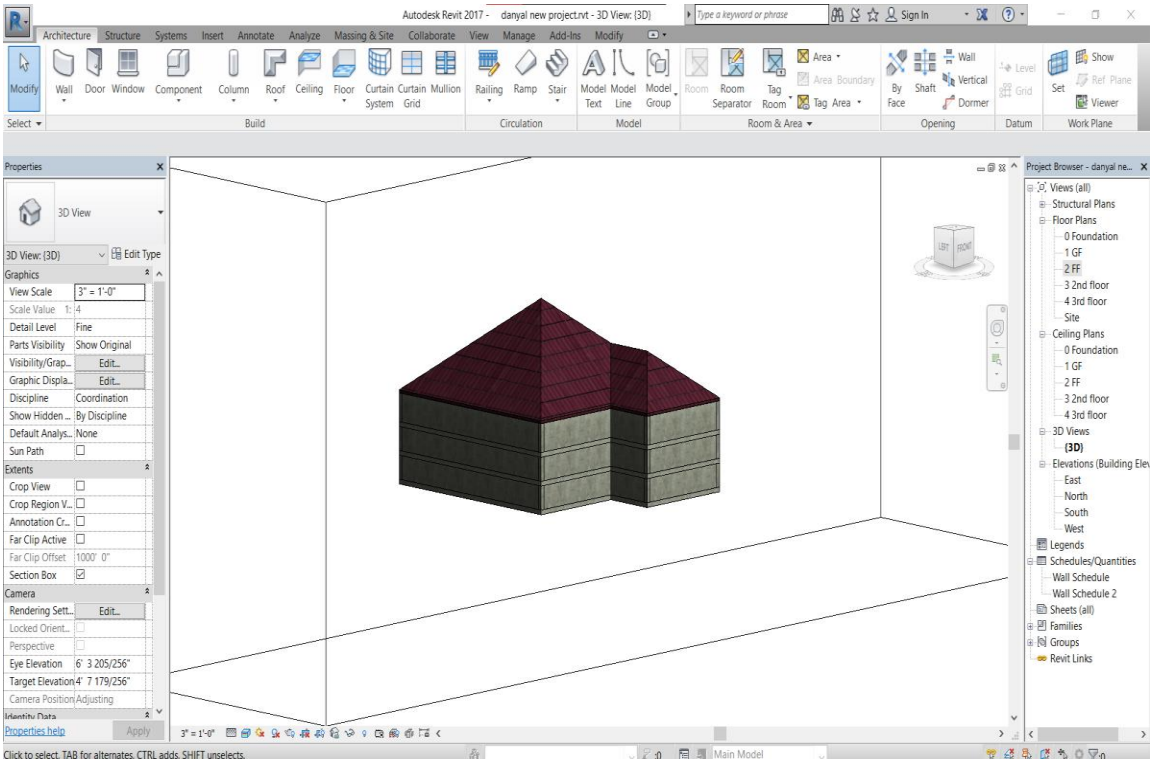


Figure 3.10 Revit BIM Model

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction:

In this chapter, the working of BIM inventory monitor plugin will be enlightened to show the functionality of the plugin and its usage.

4.2 Focus of developed plug-in:

This research work includes the integration of BIM, IOT and inventory management to address the problem in material management in construction site for accurate record keeping of material. The plug-in is entitled as BIM inventory monitor plug-in . the plugin focuses on:

- Comparing planned quantities with actual quantities
- Report the material used after activating sensors data when required for activities.
- Calculate the quantities of required upcoming activities to migitate delay in schedule.
- Calculate the commutative quantities for every activity to control the economic factor in the project.
- Record keeping of all data in database for future investigation.

4.3 Crosswork Process Map of BIMP

The cross functional process map of the BIM-IMP is shown in Fig 4.1

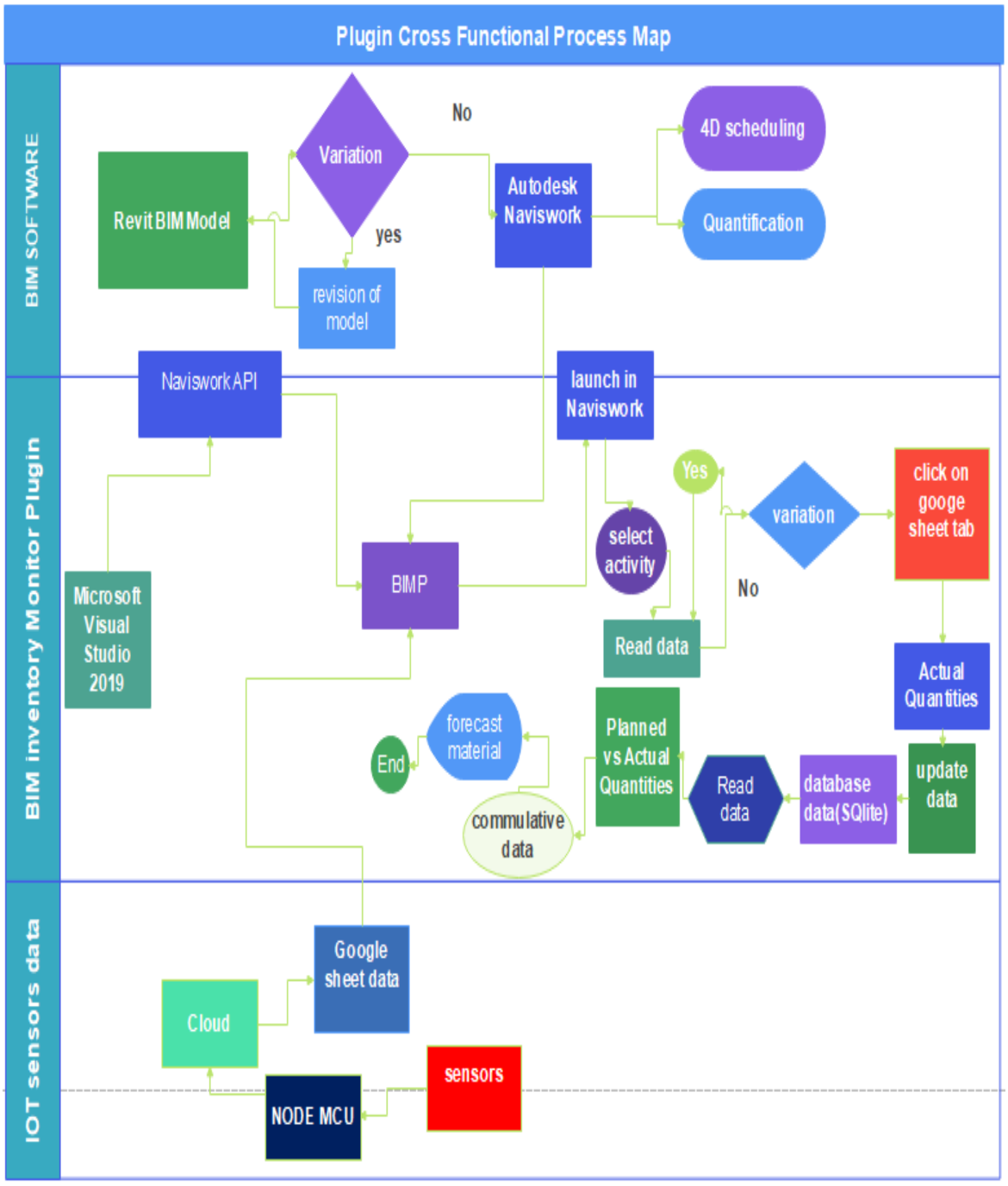


Fig 4.1 Cross Functional Process Map

4.4 Plug-in prototype architecture:

The tool was made according to the recommendation of literature review and industry experts. The plugin was developed for support of decision-making process in material management within BIM environment in order to reduce the delay in schedule and avoid cost overrun in material management.

4.4.1 Pre requisite steps before invoke the Plug-In tab

- Firstly BIM model is developed in Autodesk Revit comprising architecture ,Structure and MEP models.as shown in fig 4.2
- Afterward, the BIM model is imported in Autodesk Navisworks .
- Pop-up the quantification tab, to calculate the planned quantities in term of volume(ft3).
- In scheduling tab, activities were created based on BIM model.
- Planned start and end dates were implied on the activities.
- BIM model elements were then assigned on the respective activities .
- Activate the IOT based sensors and configure it in order to get the real time data.
- Do calibration of the sensors prototype to find least error and calibration factor

- Data will be transfer from google sheet to the developed plug-in.

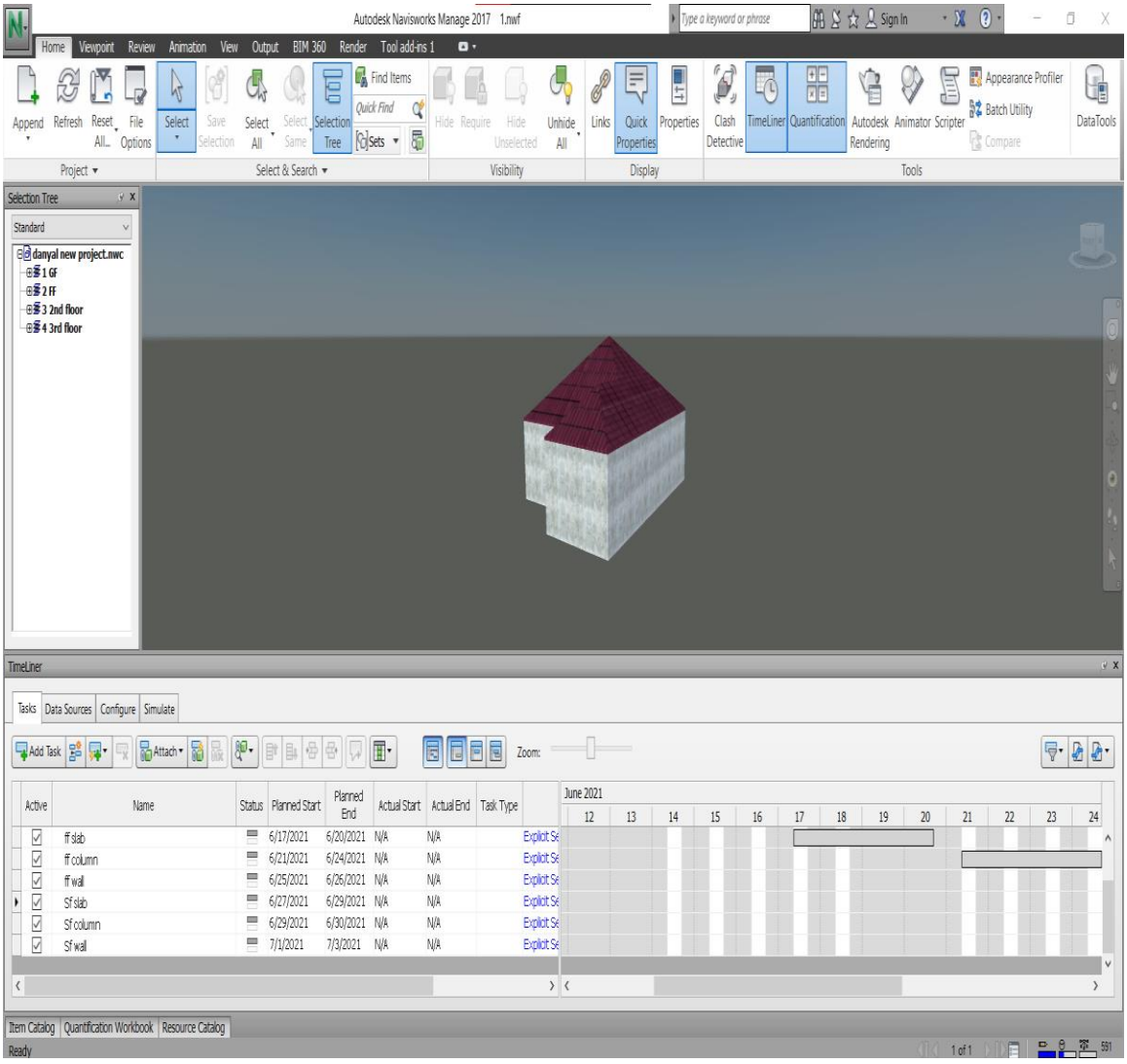
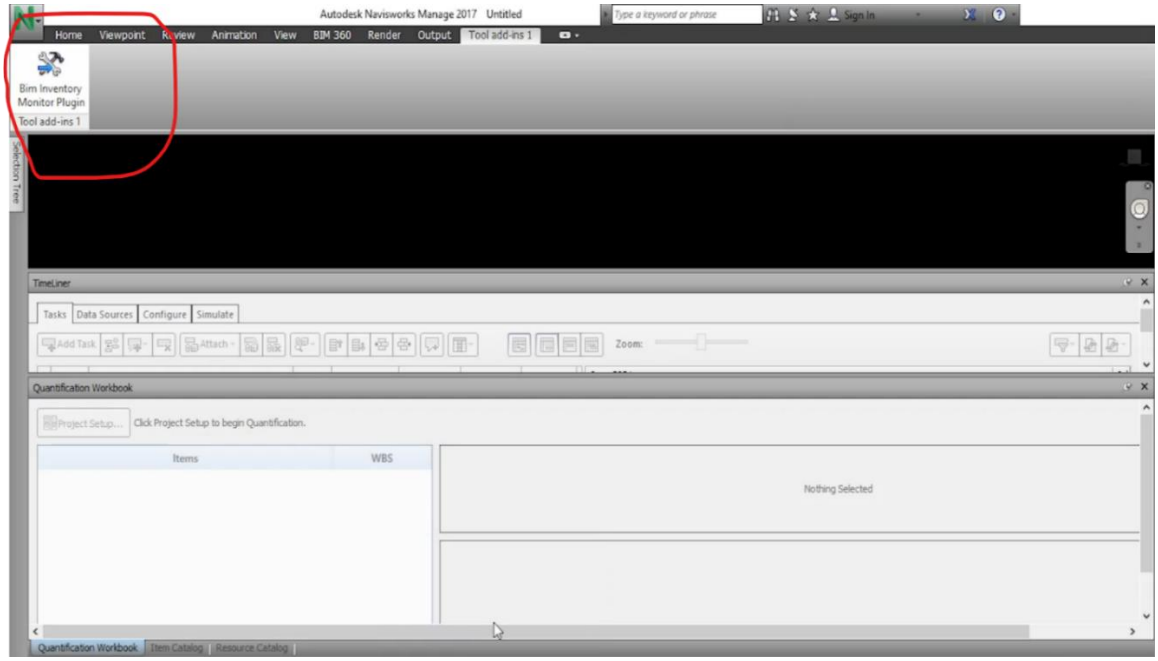


Figure 4.2 BIM MODEL IN NAVISWORKS

4.6 After invoking the BIMP in Navisworks

click on the BIM Inventory monitor plugin as shown in the figure.4.3

- 

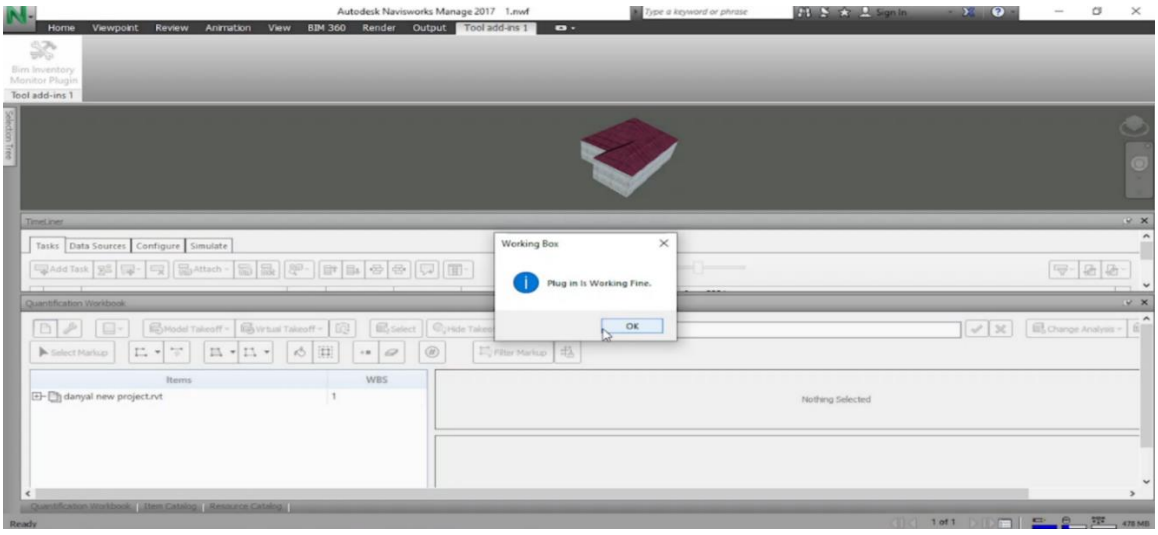


Figure 4.3 Plugin start

- To functional the plugin , check on the activity that comes on that particular planned dates and then click on open activity-single button followed by read database button, eventually the data will be shown in plugin of selected activity. As shown in fig 4.4

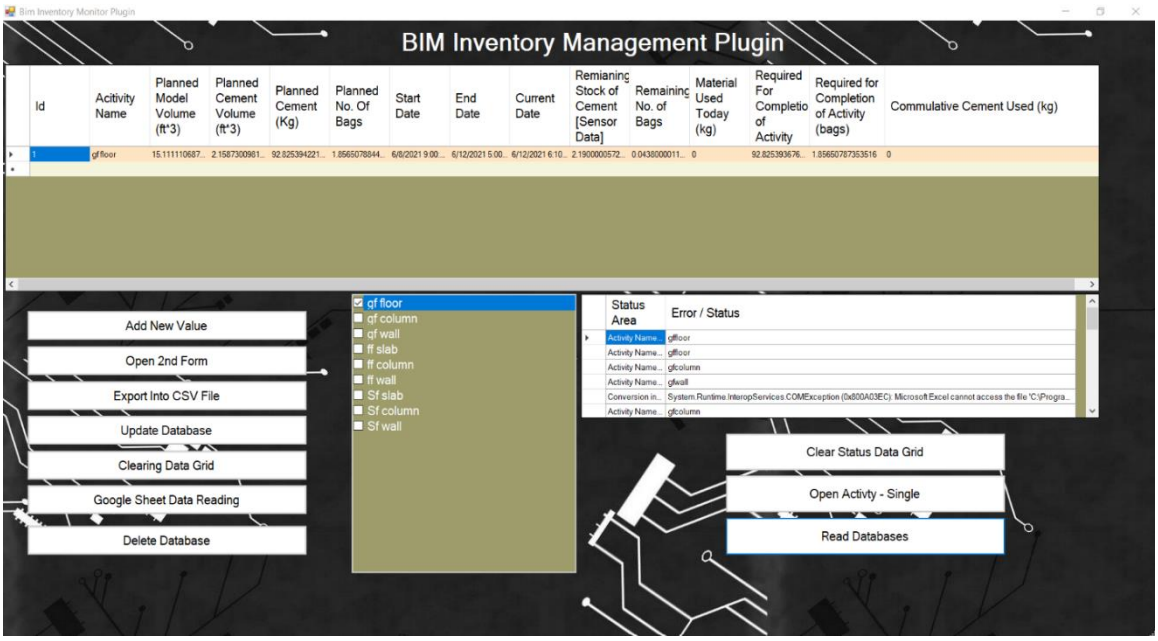


Figure 4.4 Select Activity

- Click on the google sheet tab, where sensors data is imported automatically in sensors-built column. The coding is done in this way that values come in that particular activity that confronts with its planned start and planned end as assigned for the activities.

- In order to check the material update of an activity, click on the add new value button , followed by update database button, eventually data will be updated. After that click on clear data grid button, again click on read database.so new value will be added.as shown in fig 4.5

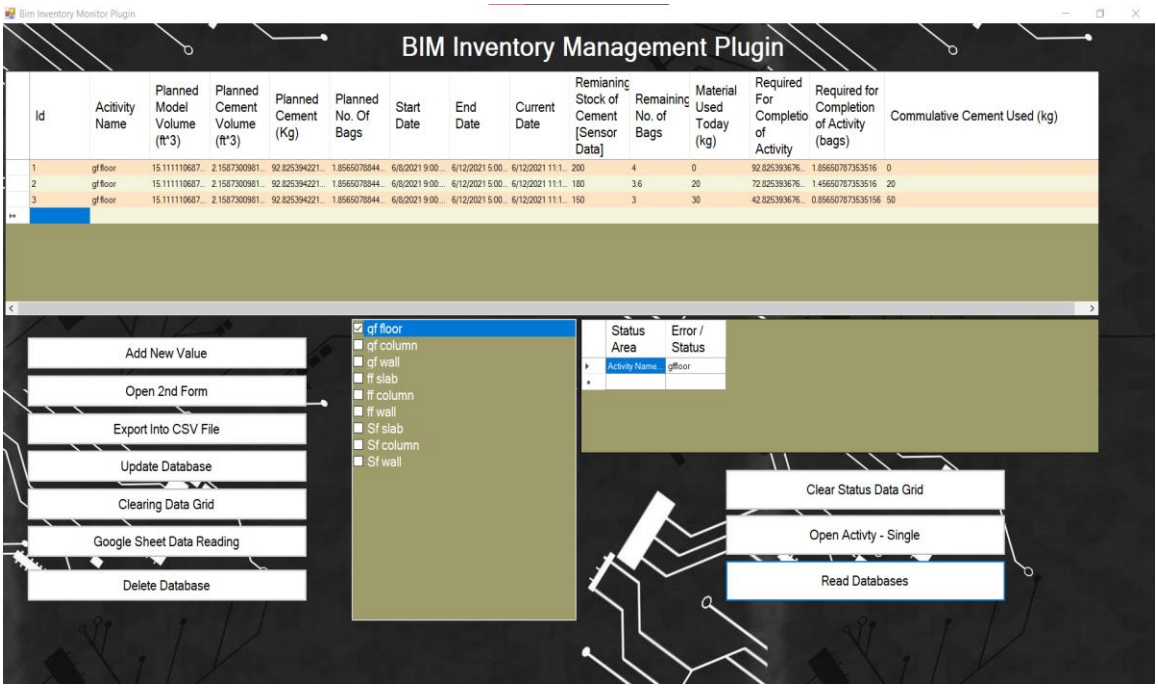


Figure 4.5 Sensors Data Import

- This grid box is designed to show the event happening message and show any error occur in the event that is done if not occurring properly. As shown in fig 4.6

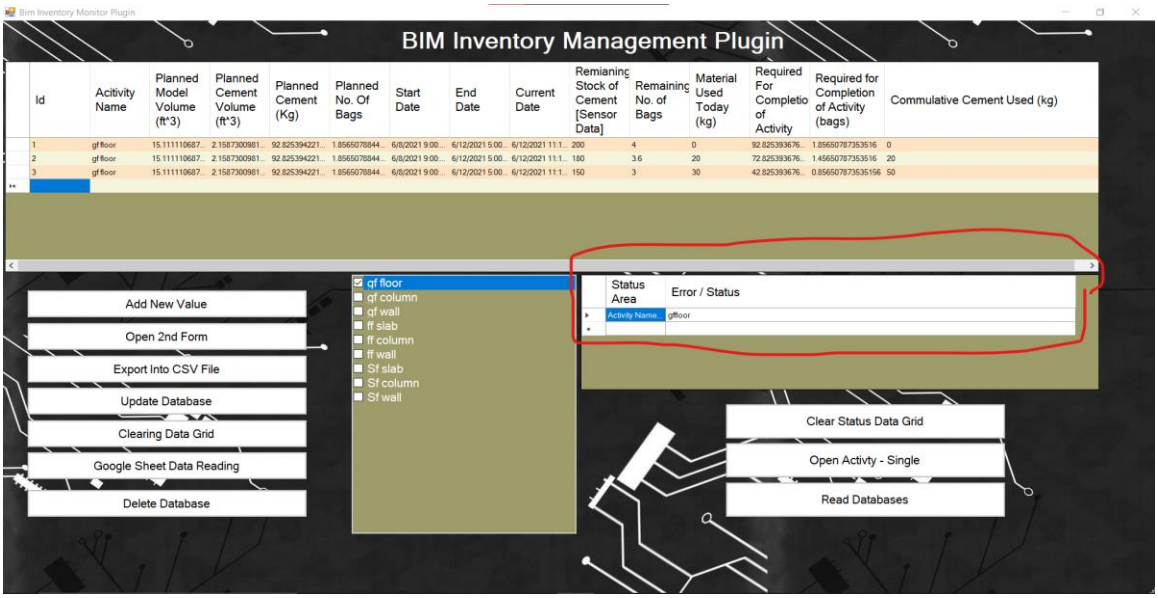


Figure 4.6 Grid box to show error

- At the end of day, if want to check the required volume of a successive activities in order to reduce the delay or late progress of project, first select the successive activites , after that click on 2nd form tab.

- In this tab, we select the desired successive activities and calculate the required stocks of it for timely order of the material.as shown in fig 4.7

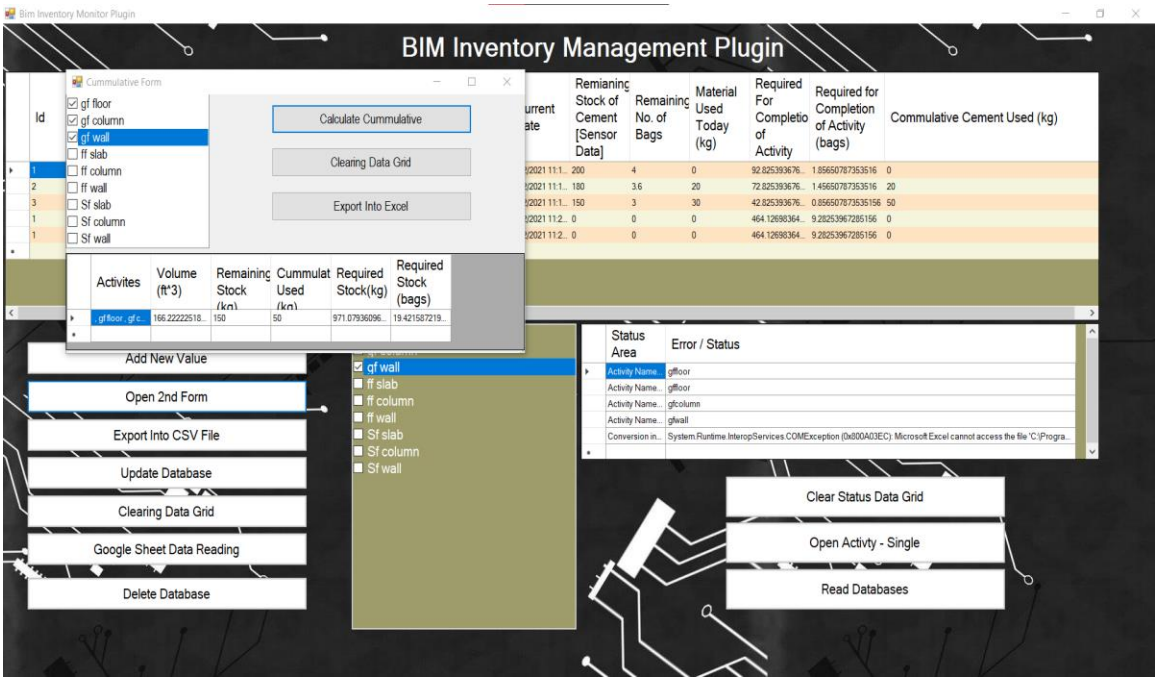


Figure 4.7 Calculate Successive Activities

- For record management system, the database is devised within the Navisworks file using SQLite, so when we close the plugin, record is saved in Navisworks file.

- To retrieve the previous data on other day, click on the read data base again, data will be restored again.

- For understanding of the layman, an excel sheet export function in CSV format has been added to make the final summary.

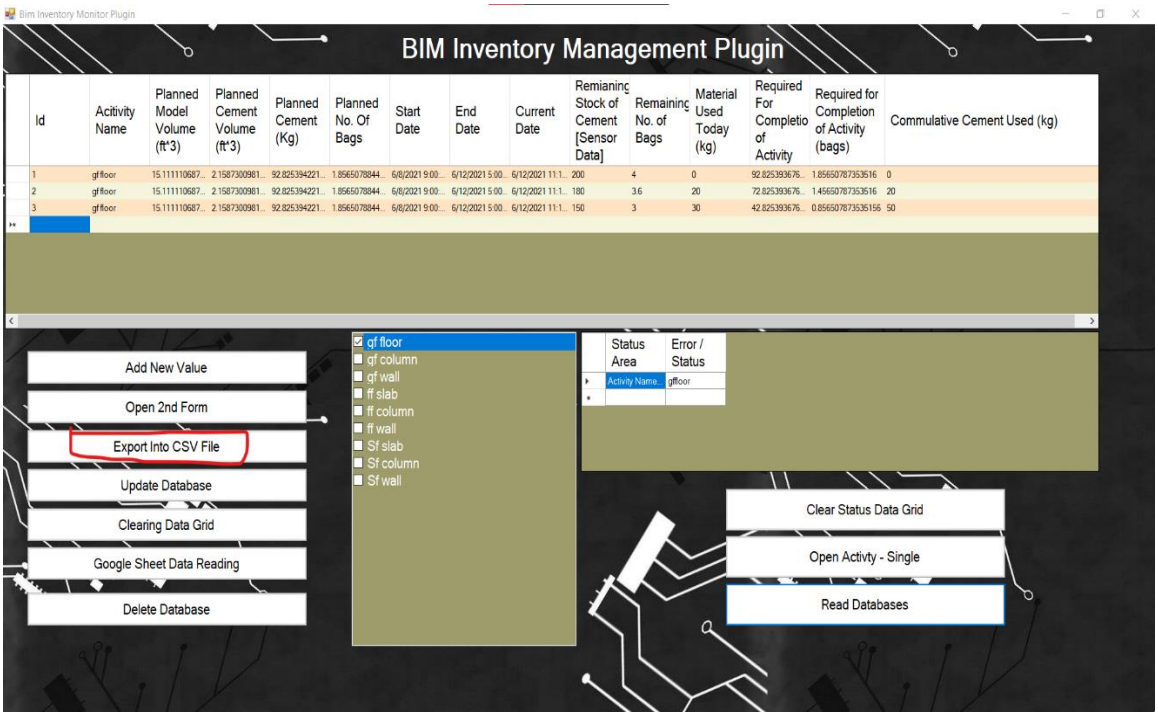


Figure 4.8 Export to Excel

Prototype validation.

The whole research design was made keeping in view the practical implementation of BIM on actual projects. Before creating the plugin, opinion was also taken from 3 industry experts about the prototype development to confirm its importance and implementation in the field. Further its functionality and design were discussed with the experts. After that BIM based inventory management system was developed and tested.

CHAPTER 5

CONCLUSION AND RECOMMENDATION:

5.1 Introduction

This chapter include the research by stating the conclusions, limitations and recommendations.

5.2 Conclusion:

The current research possesses an intelligent BIM workflow that will provide and assist the project planners for effective planning and decision-making process in construction projects. BIM is basically the digital explanation of every aspect of construction activity. It can lead to time saving and cost effectives in the project lifecycle .BIM provide benefits to every key area of construction i.e Risk management, Safety management, facility management ,sustainability etc In traditional construction project ,the material cost is high but the management of material affect the project schedule is about 80%.

The BIM itself does not provide services for real time inventory management service but due to open API, one can utilize by creating different prototypes for it. Subsequently, a BIM based Plugin is created for real time inventory material management. The prototype was developed in C# language using Microsoft visual language. a data base connection was developed in SQLite. The tool will be helpful in daily real time monitoring of material with accurate output within BIM project. However, a non-BIM user can also get information inform of excel sheets which is also a beneficial feature of the tool.

This will also provide record of stocking material for future investigation. . Before development of plugin, expert opinion were taken into account regarding its importance and functionality in the market. Further design of plugin was discussed.

5.3 Limitation

- The tool can be used for only unconfined material i.e cement sand ,aggregate.
- Materials like steel and other miscellanary items cannot be monitored through it.
- Parallel activities cannot be tracked, only 1 activity can be tracked at a time.
- The concrete ratio can be used only one at a time i.e for every activity you can used only one type of ratio.
- The prototype cannot predict whether the values that come through load sensors are actually the required materials because it is not a image based detection.
- The plugin can only work on x64 based system.
- The plugin will only work on Autodesk Navisworks 2017 .

5.4 Future recommendation

Although the primary features and functionalities of the plugin have been thoroughly described earlier, there is still potential for improvement. The current study, as well as the application it generates, can be further enhanced for inventory management and site logistics**.** The following plugin can also develop and enhanced for other items using other iot devices, Laser technology, drones or image-based cameras could be used for more accurate and precise tracking of real time data. we can also used bar code system for the material. The plugin should be linked with 5D and other BIM dimensions for fully potential use and make it sophisticated. Also vendors selection option can be added for timely order delivery and project progress.

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