

Applications of 5D CAD for Billing in Construction using GIS



Pranav Andhyal, Karthik Nagarajan, Raju Narwade

Abstract: A Construction project involves project management and financial planning at various stages right from the concept stage to the execution stage. This involves a large number of people working on different aspects of the project adhering to their specific job roles in collaboration with the others. These members not only work on the different aspects but also work on different software's and platforms in order to create a holistic working plan to ensure timely and flawless construction activities. But these software's only provide specific information feeded to it. A single program which would provide information of all these software's collectively on one platform would not only make it convenient for sharing data but also help in reducing the delay and eliminating errors. A 5D model can be created linking the schedule of the project and the cost involved in it to the drawings on a GIS platform. In this research a 5D model of a Residential cum Commercial project Located in Prabhadevi, Mumbai, Maharashtra, India has been generated. This model includes the data related to the Schedule and Cost of the project, which can help in making decisions related to monetary aspects, Men & Material preparedness, verification of bills & Billing Audits. A 5D model holds Spatial data such as Project Schedule, Itemized Element costs and Quantities along with the 3D model of the structure. The conclusion of the study states that a GIS Model can serve as a real time data base for all the parties involved in the project at every level of its progression.

Keywords: CAD, Project Management, Billing, GIS, 5D Model.

I. INTRODUCTION

The most important industry in the development of a nation in the construction industry, may it be Infrastructure or Real Estate. The construction industry is recognized as the second largest employer in our country. Hence it becomes very important for the industry to function uninterruptedly at every level. For any project to be successful it is mandatory to be planned in detail with respect to execution and also monetary aspects. These factors eventually lead to optimum utility of time and manpower of the agencies involved. Which is also the main objective of every management to

avoid failure of the project cycle and identify problems and deviations from the specifics well in time and take necessary actions. All this can be done by collecting real time data from the team and ensuring synchronized efforts towards a common goal.

A. Existing Scenario

A construction project involves addressing a number of activities and achieving the targets as per the pre-planned schedule. Along with it the stages of planning the finances of a project also play a key role in maintaining the constant progress of the project. This involves primarily the management of cash flow and the timely payment to the contractors and vendors. In general practice this is done by making lengthy calculation of the quantities of material and its cost of procurement and installation. But this alone is not enough as the spatial and nonspatial information are not unified in a single system. Thus, to achieve this construction industry needs a constant effort towards developing effective mechanism. There is a need for a single platform for all spatial and nonspatial data for efficient financial planning. Due to recent advancements we can now generate a 3D model of the project and link the project schedule to create a 4D model in GIS and going further we can also link the cost aspect related to it to make it a 5D model. This provides a virtual model of the project and also the relevant time and cost aspects are easy to access and understand on a single platform.

B. Application of GIS for Billing in Construction

Geographical Information System- GIS is a layered system wherein the data is captured, stored and analyzed & Construction Billing involves verifying of the constructed element with respect to the CAD drawings, Item specifications, rates and certifying the claimed amount with necessary corrections. Due to advancement in GIS it can become easy to imbibe all this data in a single data base along with a 3D model generated using CAD reducing the time taken for the process saving on the precious man hours. Recent GIS development can be used to verify the data in accordance to the claimed bills by the contractor and certifying the same, also identifying and correcting any errors or foul claims. Identify the deviation from the pre-determined specifications and its cost impact. It also can be used for Billing audits, and re-verifications. Not only this but the execution and project planning teams often unaware of the cost impacts of the tasks can also be aware of the cost implications of the activities undertaken by them.

C. 5D GIS model

A GIS system can be used to store project relevant information and can be modified whenever necessary.

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* Correspondence Author

Pranav Andhyal*, Student, Department of Civil Engineering, Pillai's HOC College of Engineering and Technology, Rasayani, Panvel, India. Email: pranav.andhyal@gmail.com

Karthik Nagarajan, Associate Professor, Department of Civil Engineering, Pillai's HOC College of Engineering and Technology, Rasayani, Panvel, India. Email: knagarajan@mes.ac.in

Raju Narwade, Associate Professor, Department of Civil Engineering, Pillai's HOC College of Engineering and Technology, Rasayani, Panvel, India. Email: rnarwade@mes.ac.in

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It can work similar to a Building Information Model (BIM) once all the data required for making it a 5D model is feeded which can be further used at every stage of the project. A GIS model linked with construction schedule can be linked to develop a runtime application using Visual Studios to help the management to Monitor the construction Progress. Using a 3D model with georeferencing it becomes convenient in creating an efficient site layout & solving logistic issues. A GIS model can be used to present the project status to all the people concerned with the project viz. executing, planning, billing engineers, non-engineers, the management which often includes non-engineers and other stakeholders as- well in an easy format. It can be bought into use right from concept stage of the project to the post construction phases for site management, Budgeting, Bill Verification, Technical Audits, managing the inventory and supply chain management as well without switching to multiple applications at a time. GIS can also function as an effective tool for Document Control such as Drawings, Design proposals, Information Requests, pour cards, document transmittals, Bills, BOQs, methodologies and many more which can be shared with the concerned members in the project team or reviewed by the management for any decision making using the available analytical tools.

D. Research Objective

For developing a holistic model, it is necessary to gather all CAD drawings, construction schedule, Quantities, Specifications, and Cost along with all spatial and non-spatial data, all document related to the project in a single interface. Hence, the objective of this research is to create an information model using GIS interface and verify its utility in efficient & error-free billing. The objective was accomplished in the following manner:

Creating a database by linking CAD drawings, Construction Schedule & Element wise Cost of the structure to develop a 5D model to be used for

1. Monitoring the project progress.
2. Linking all project related information.
3. Preparing Cash flow and cost projections
4. Preparing Bills for Contractors and vendors
5. Verifying and certifying Bill claimed by the contractors.
6. Identifying Deviation from the specifications and eliminating errors.
7. Facilitating ease in Periodic Bill audits during & after the construction.

II. LITERATURE REVIEW

Divyashree Yadav et al. (2020), had researched how buildings can be placed according to urban streel planning using urban extraction from high-resolution satellite data. **Shrenik Shah et al. (2020)**, in this study the author has used 3D modeling techniques in Mumbai city for assessment of urban utilities. **Panaskar S et al. (2019)**, have worked on land use and land cover maps which helps in the extraction of NDVI and NDWI index. **Arya Vijayan et al. (2019)**, took the Internet of Things (IoT) as a platform for monitoring various parameters in the construction industry. **Biradar Shilpa et al. (2019)**, has used e-waste as an alternative in concrete which can be a good alternative for coarse aggragate in construction. **Chowdary Mohanlal et al. (2019)**, has research and applied the 4D GIS model in construction management over Ulwe in the Navi Mumbai area and has

shown a good interpretation of GIS with Construction management. **Mahesh S. Singh et al. (2019)**, have explained in h=their paper the concept of labor productivity and analyzing using RII. **Pallavi Patil et al. (2019)**, has applied re modified minimum moment method as a part of the infrastructural project in the construction industry. **Shobana Jadhav et al. (2019)**, have applied GIS for the best feasible transportation route analysis for delivering RMC to the site. **Aditya Shatri et al. (2019)**, in this research the authors have integrated land using zoning for optimizing vacant space for urbanization which can help in construction activities. **Karthik N et al. (2016)**, in this research the author has used Etabs for multistoried building considering the effects of infill walls.

III. METHODOLOGY

A systematic methodology has been established to create an interlink between the CAD drawings, Project Schedule & the Element wise Cost sheet on a GIS interface. AutoCAD 2019 was used for 2D drawings, Ms. Project 2010 was used for preparing the schedule and Ms. Excel was used for preparing the itemized & Element wise cost sheet of the building. All these were imported in QGIS 3. Fig. 1 shows the flow chart of the steps involved for developing this 5D model.

A. GIS Approach

A.1. Collecting 2D Plans

All necessary Structural and Architectural plans are to be collected from the respective consultants. These drawing are to be checked for any discrepancy and necessary corrections are to be made in the drafting with respect to the layers, colors, incomplete polylines and so on with the help of AutoCAD. It is preferred to have closed and solid filled polylines to generate a solid 3D model in QGIS.

A.2. Importing of CAD Drawings to GIS Interface

The AutoCAD file with *.dwg (drawing) extension is to be saved as *.dxf (drawing exchange format) so that it can be imported into QGIS. To import the text layers in the drawing files special plugin needs to be installed. Drawings imported into QGIS can be superimposed upon geospatial image with respect to the co-ordinates on specific convenient locations of the drawings. This process is called geo-referencing. After this, the drawings can be digitized to vector form shape files in point, line or polygon shapes. Otherwise, it has to be ensured that all the layers of the drawings are to be imported to QGIS with a same reference point, or else the drawings will not be superimposed, and a correct model will not be generated

A.3. Creating Database For Structural Elements

Data relevant to the specific shape files viz. schedule of starting and end date of activity, volume of concrete, quantity of formwork and reinforcement, Grade of concrete, elevation and height of the object, rates of unit work, and cost of the works can be linked in from of attributes in the attributes table. These attributes have to be developed, calculated in excel or Ms. Project and saved as .csv (comma delimited) format so that they can be imported into QGIS and joined to the shape files.



These attributes can be modified as and when required and be updated with the shape file very conveniently. QGIS also allows mathematical calculations for working out the quantities, Summations and other analysis.

A.4. Extruding 2D to 3D

Extruding of the 2D drawing to 3D needs a special plug-in Qgis2threejs. This plugin has to be downloaded from the internet. This plugin once installed has to be run, this opens a separate HTML window. The window shows a layer's panel on left side of it, while the rest of the window displays the 3D model. To see the 3D model, we need to enable the preview option and by selecting each layer at a time its elevation and height has to be specified in its properties. The QGIS also facilitates the elevation and height of the element to be directly taken from the attributes table. Once done with the steps, a 3D model is generated and can be viewed from all angles as per our requirement

B. Management Approach

B.1. Identifying Activities

In a construction project a number of activities and their relevant expenditure are to be predetermined and necessary funds are to be arranged accordingly. These activities are identified and planned in sequence of logic and priorities in accordance to the work schedule. This gives a systematic budget of the project and also the schedule of expenditure to be made in form of vendor payments, monthly RA bills, payments for statutory approvals and many more. Once these activities, monthly targets and their relevant cost are determined it makes it easy to make decisions and optimizing the fund utilization. Depending on it, management can take call upon further value additions and cost saving measures.

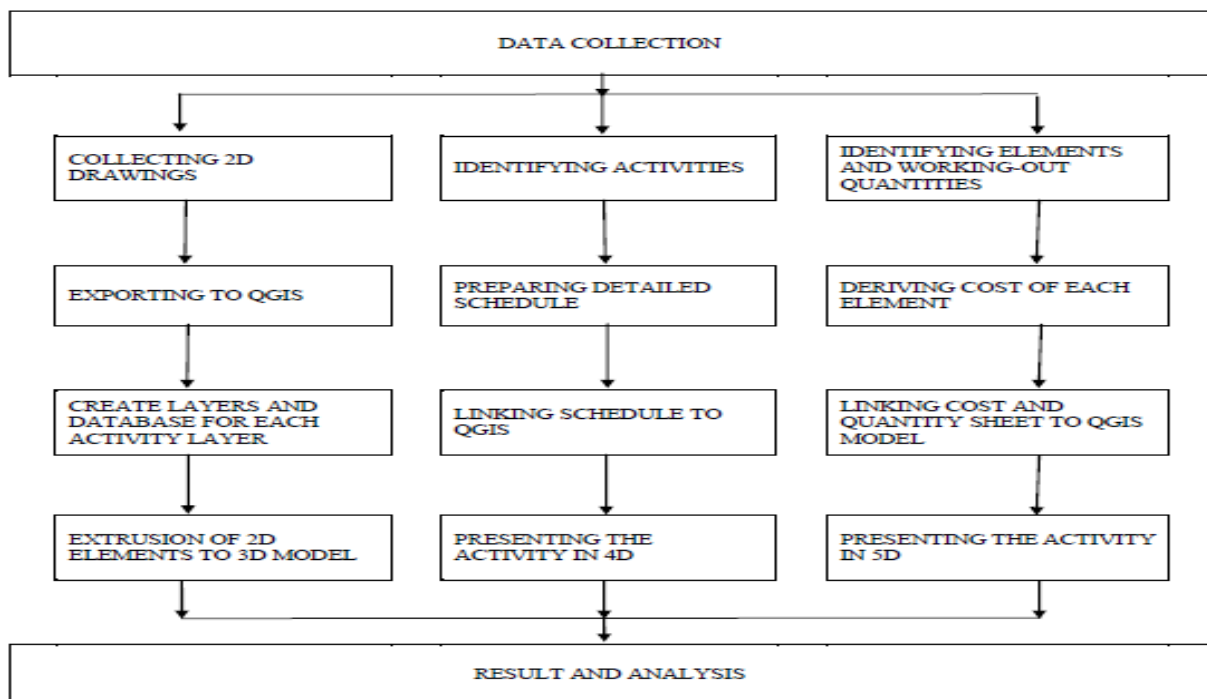


Fig. 1. Flowchart for developing a 5D model

B.2. Prepare and Updating the Schedule

The activities of the project are planned using Microsoft Project 2010 based upon the work breakdown structure. For convenience of understanding and working it has to be ensured that the activity in Ms. Project and the corresponding shape file layer in QGIS are named the same. Microsoft Project schedule shows the start date, the end date, the Duration of activities, delays, critical paths and the inter-relation between the activities. Thus, whenever there is a change in the schedule, it has to be updated immediately to have a real-time update of the project status and can be share with all the concerned

B.3. Linking of Schedule to Create A 4D Model

The schedule generated in Ms. Project has to be saved with an extension of *.csv (comma separated value) so that it can be imported in QGIS and further linked to the element's respective shape file. This linkage can be further updated as and when the schedule of activities is changed. Once this

linking is completed, the final output is nothing but a 4D model i.e. a 3D model with a time component.

B.4. Linking of Quantities and Cost to Create A 5D Model

Similar to joining the activity schedule, the element wise quantity and cost sheet also has to be linked with the corresponding shape file. This generates a 5D model, i.e. a 3D model with time aspect and also the cost aspect linked to it. The quantities and cost also can be modified and updated as and when the design, drawings or specifications are changed. This 5D model can now be used for preparing budget, forecasting expenses, Allocation and reserving funds, Verification of Bills, Verification of Quantities & also Material management all on a single interface.

IV. SITE LOCATION & IMPLEMENTATION

The research was conducted on a commercial project with 3 basements & G+19 Storeys tower including a movie theatre and multi-storey parking in it. This project is located at Prabhadevi, Mumbai, Maharashtra, India shown in Fig. 2 and Fig. 3 QGIS was used to create the model as it is cable of viewing, collaborating and storing information from various software's on a single platform and also track and update the project progress, enabling the billing team to review and verify the contractors claim for the executed work. For this research we divided the project into two basic stages, the Substructure and superstructure. For the convenience and focusing more on the cost aspect we have considered all the beams of same depth, the slabs of same depth and the floors above the theatre are also considered typical except for refuge floors.



Fig. 2. Satellite image of the site location

A. Creating 3D Model

The first step to create a 5D model is to collect all the required CAD drawings. In these drawings the elements are then identified according to which the QGIS model is to be prepared. Then the drawings are corrected to ensure all the element layers are in closed polyline. Now as we are not using the georeferencing technique to superimpose the drawings in layers, we need to create a different AutoCAD file which we may refer as a working drawing file in which a specific point with reference to which the drawings are to be superimposed is fixed. Further, the elements are copied from the original drawing file with reference to that specific point and superimposed in the working drawing. The element now needs to be solid hatched so that the 3D extruded model in QGIS also appears as a solid object. Now the working drawing need to be saved as a *.dxf file and imported in QGIS. Once imported in QGIS the *.dxf file now needs to be again exported as a *.shp file that is the shapefile format to which the attributes, i.e. the desired data can be linked or attached. Now once all the shape files are created, we can remove the dxf files from the model. To create a 3D model of the structure, the Qgis2threejs plugin is installed and run. In the properties of each shape file vector layer in HTML window the extrusion height of the element and the Elevation of the element is specified. This data can be a manual input of directly from the attribute table linked to that element or the out-come of arithmetic calculation of a number of attribute values. Once the elevation and depth of the element are specified the preview option allows us to see the virtual model of the building. The opacity of the elements, the color of the elements and other such properties can be changed and modified as per our requirement from the layer properties. Also, the lights, camera, background and environment of the 3D model can be changed with the options available in QGIS. The figure 4 to figure 14 gives the complete details of the process of concerting a 2D cad drawing into 5D model.

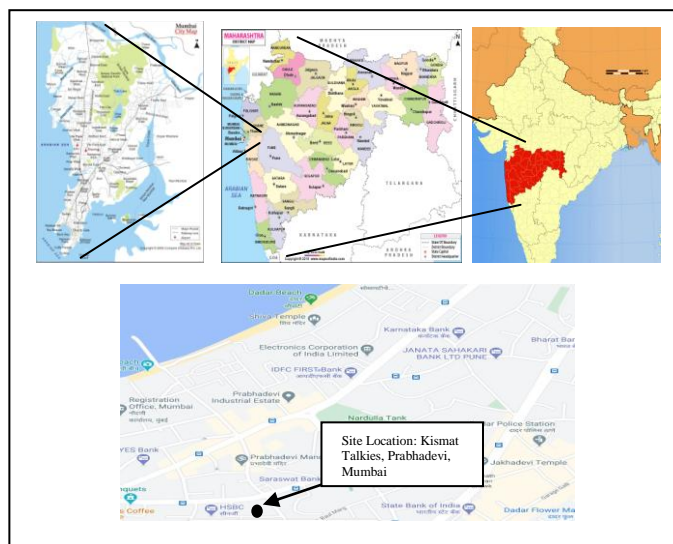


Fig. 3. Study area map

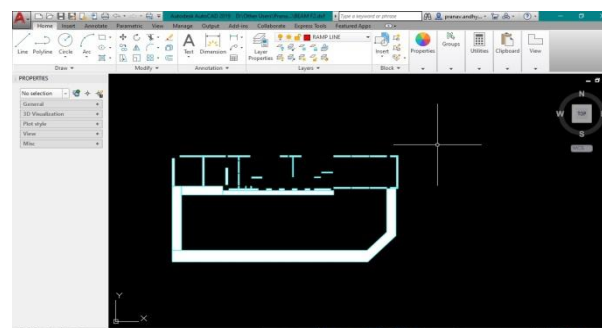


Fig. 4. Preparation of AutoCAD drawing with closed polyline and Hatch

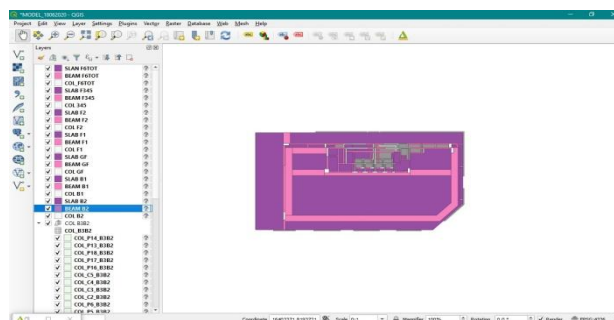


Fig. 5. OGIS Shape file layers

Fig. 6. Microsoft Excel sheet for Quantity & Cost of the element

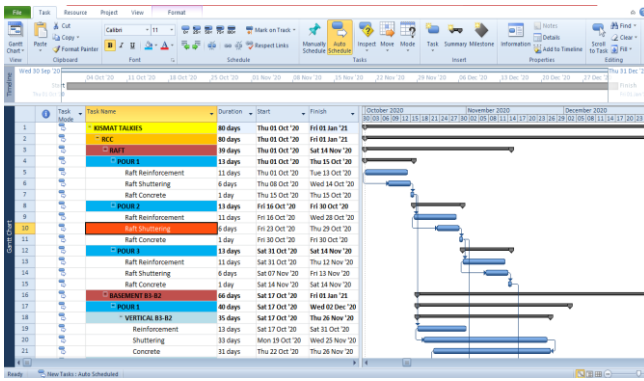


Fig. 7. Microsoft Project Schedule

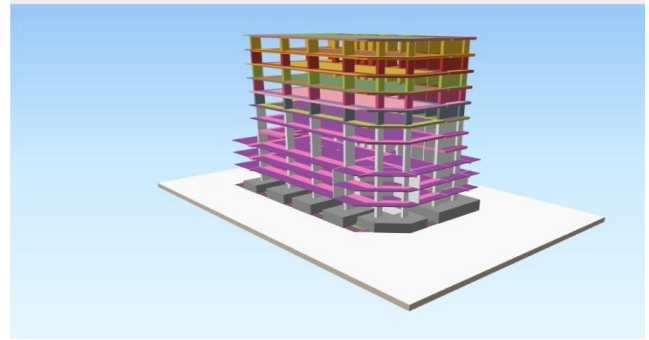


Fig. 11. Step by step progression of the 3D model

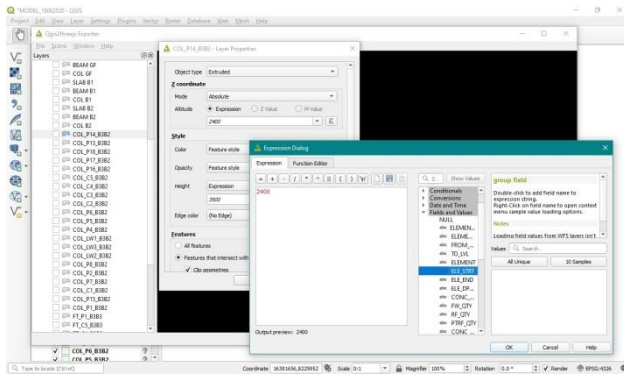


Fig. 8. Assigning Elevation and Height for 3D Extrusion of individual elements

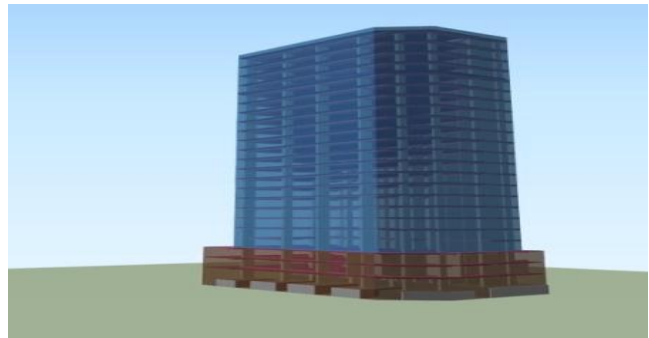


Fig. 12. A complete 3D model of the Building

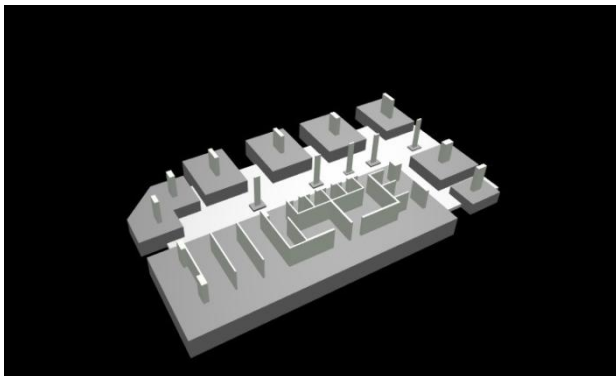


Fig. 9. 3D model of Footings and verticals above it

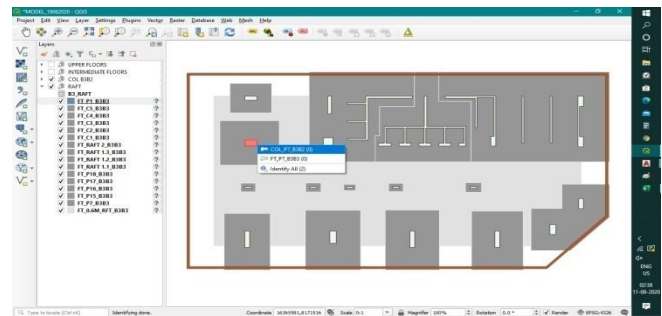


Fig. 13. Selecting an element to view the attributes

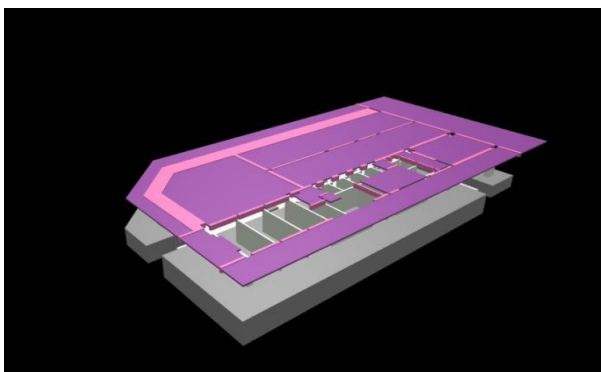


Fig. 10. 3D model representing Beams and Slab at 3rd Basement level

QUANTITY	UNIT	PRICE	TOTAL
1.00	CU.M	100.00	100.00
2.00	CU.M	200.00	200.00
3.00	CU.M	300.00	300.00
4.00	CU.M	400.00	400.00
5.00	CU.M	500.00	500.00
6.00	CU.M	600.00	600.00
7.00	CU.M	700.00	700.00
8.00	CU.M	800.00	800.00
9.00	CU.M	900.00	900.00
10.00	CU.M	1000.00	10000.00
TOTAL			12000.00

Fig. 14. Attribute Table representing the Quantities and cost of the selected element.

B. Scheduling Activities

The work breakdown structure forms a guide for preparing the schedule of activities of the structure. Most of the projects are planned using Critical path method (CPM) or bar-chart method. But Program evaluation and review technique is also another method that can be used for scheduling the activities. PERT involves the terminologies such as Slack time, Earliest and Latest start Time, and Earliest and Latest End time.

But CPM method gives advantage of completing the activities within minimum duration by identifying the critical paths. The project duration and activities in it are divided into parts. The activities & their start and end time are determined and milestones are set at an end of a group of certain activities. In this research, the schedule was prepared using Microsoft Project 2010. It had the complete list of activities with their start and end dates, duration of activity for all the elements of the structure. Once the schedule is completed in all respects, it is then saved as *.csv file, which is the acceptable format in QGIS. Only then this data can be linked to the shape file as attributes. It has to be made sure that the elements named in the Microsoft projects should be the same as name of QGIS Shape file.

C. Quantities and Cost

For all the monetary aspects the most important requirements are the Quantities, Rates and Cost. They form the basis for preparing the budget, Material procurement, Cashflow, Bill claims & verification and Financial Audits. The quantities of the elements of the building are calculated in Microsoft Excel. The corresponding rates are added for the elements and multiplied with the quantities to derive the cost of the element. This sheet is saved with *.csv extension to make it importable in QGIS. This sheet is linked with the QGIS layers of specific elements individually. Thus, when the linking is completed, all the information related to the time and cost of the components is available easily without having to switch between multiple software's for drawings, Schedules and cost. Now the complete information of the start time of the activity the material required for it, the material specification, the rate at which the material is to be paid for, the cost of the element of work, its dimensions everything is seen in a single window. This data can be summed to find the cost of a particular set of activities using QGIS tools. This can be used for predetermining the monthly expenses and reserving funds for the same. It can help in error free checking of bills within less time using a virtual model and data base linked to it. Eventually saving the valuable manhours

V. RESULTS AND ANALYSIS

A. Problem Identification

In a construction project with intricate design it is sometimes quite obvious to have different interpretations of the drawing due to difference of visualization ability. And this may lead to serious mistakes having big cost and time implications. But a virtual model eliminates the chances of confusion and clearly represents the 2D drawings in 3D form sparing the possible chaos. With all the data linked with the specifications of the shape and dimension and elevation it facilitates the execution team in better understanding and saving on their time of going through multiple drawings and layouts for executing a task.

B. Budget and cashflow

In a construction project right from the starting to the end of it the budget has to be monitored and controlled. With a 5D model it becomes convenient to keep an update of the progress of the work as well as the cost executed. The Planning of periodic cash flow can also be done with the help of QGIS 5D model as it gives the tasks to be performed in a specific period and relevant cost of executing it, thus the funds can be arranged or reserved in advance. For example, if

in this project the footings and a set of columns is to be casted in the first month, then the cost of executing these elements to be paid to the vendors and contractors can be arranged well in advance. Similarly, for further months also, the schedule and corresponding amount can be estimated and necessary arrangements can be made for the entire project duration.

C. Easy verification of Bills

At the completion of works of every month, the contractors and vendors raise a claim in the form of Monthly Running Account Bills for the works executed in that month. Usually the traditional process is to accept the bills through a document control system in form of soft copy, Hard copy and all relevant drawings and documents. Once this procedure is cleared and finally the bill is accepted the bills are to be checked and certified within 21 days from the date of submission of the bills. In large projects there are multiple no. of contractors and vendors who submit the bills; hence the billing team is under tremendous pressure and work load eventually resulting in errors and bill verifications, often certifying foul claims, and sometimes exceeding the stipulated period. The use of this model will save the time of the billing team for verifying the hard copies, soft copies, making highlights and marking on the drawings, recalculating the items quantities, verifying the specifications etc. All this information will be readily available in the model and the engineer just needs to verify the element executed during the month. The chances of errors in missing, reclaiming the elements, Deliberate foul claims, Deviation in specifications of work can be identified and necessary actions can be taken. This would save the time and efforts of the team ensuring timely and error free completion of the work. In fact, the billing engineer can himself proactively keep an update of work on daily basis and pre certify the bill with all information readily available at his fingertips.

D. Material Readiness

One of the key elements responsible for the success of the schedule of the project is the Material availability. For this it is very important to know in advance the material quantities so that they can be procured in time. A QGIS model will give the detailed forecast of the material consumption and further requirement also. Thus, making it easy for the Store or procurement team to be prepared with their strategies, schedule and logistic plans. For example if the Initial consumption of reinforcement steel for the first month of work is 400MT and that consecutive months is 250MT, and 300MT the procurement team will then consider the storage area, Vendors, purchase orders, and necessary fund provisions and order the steel accordingly instead of excess ordering and creating logistic constraints on the site and restricting movement or Short ordering creating a shortfall of material and delaying the activity along making the workmen sit idle till the material is received.

E. Sharing of Data

It is easy to share real time status and data of the project through some web-based platform as QGIS data can be exported in .pdf, .csv or .html format. This data can be shared to any stakeholder anywhere across the globe even though he does not have access to QGIS Sharing real time database with some web-based platforms.

Also, this can be uploaded to a common local server or project database management system.

F. Handing-over and Audits

The interlinked model of 3D model + Schedule + Relevant Cost creates a holistic model thus helping and smoothening the process of handing-over the project at any stage between two parties. This database has all the required information stored in a single interface and the person taking over does not need to go through multiple software's and files to make sure he has received everything he needed. Similarly, the periodic bill audits can also be conducted taking the help of QGIS 5D model to check and verify that there have been no irregularities and errors in the billing process throughout the period.

VI. CONCLUSION

A construction of any project requires detailed planning of all its aspects and resources. Hence there is a transaction of huge amount of data right from the concept stage to its maintenance stage. This data needs to be stored in a systematic manner such that it can be reviewed at any desired stage by any concerned party. This data not only needs to be reviewed but also needs to be updated and analyzed from time to time with the progress of the activities which in turn helps in better decision making and ease of tasks such as budget control, cost projection, Bill verification and Financial Audits. The 2003 report by National institute of Standards and Technology, USA pointed out that from 1964 to 2000 the labor productivity in construction sector went down considerably causing a waste of about 4.74 billion dollars every year only due to lack of software integration and inter-operational constraints. Hence the US government initiated the National 3D-4D-BIM Program under U.S. General Service Administration. Through advancement in GIS it was noticed that GIS is also capable of Simulating the real-world information for better planning and coordination right from the planning stage till the maintenance stage of the project. In this research the spatial and nonspatial data of the building were linked together to form a holistic model which can be used throughout the lifecycle of the project. The 2D drawings were imported from AutoCAD 2019 to QGIS 3.12 platform to generate a 3D model and linked the schedule prepared in Microsoft Project 2010 to the GIS model making it 4D. further when the cost of all elements was linked it made it a 5D model. All the necessary information about the elements was linked and visible as attributes. The model can be used for monitoring, controlling the progress and the budget, Solving Problems, and Verification of bills and Audits. It is also to be noted that this software has a very user-friendly interface, it is economic and needs no expertise to work on it. Monitoring and Controlling the project progress and the budget is a critical task. One has to have a clear forecast of activities and relevant cost to avoid any time and cost overrun. Failure in controlling the Time and cost may also eventually lead to failure of the project causing serious monetary and legal implications. A details planning would instead ensure convenience in Budgeting giving a handy information of resources and cost involved in activity throughout the project in a systematic fashion. It would also be an effective tool for solving queries in execution of works and making better decisions as a 3D simulation of the project is available. It serves as a knowledge model for the participants at every stage of the project giving spatial and

nonspatial information. It helps in maintaining an up to date inventory of material required as the forecast of requirement is readily available in the model. It not only helps in Budgeting but also in verification and certification of the monthly running bills saving on huge amount of time and efforts as the quantities and specifications are also available in the attributes. Any deviation in the specification such as grades of concrete, rates of material, quantities of material in the claim can be quickly identified. All the elements can be thoroughly checked and it can also be ensured that no elements are missed or reclaimed. Resulting in timely certification of bills and maintaining a steady cashflow for both contractor and the client. In case of Handing over, Closure, Termination of contract, Loan applications and Audits, the GIS model serves as an Information or a knowledge model where all the relevant information is readily available and updated timely resulting in smooth transitions and verifications. The data in the model can be easily converted and exported in the form of pdf, Excel files whereas the 3D model can be exported in Image as well as an animation for. This makes it presentable and convenient to communicate to the concerned even without having access to the GIS interface The research strongly recommends the application of 5D model using GIS interface in construction management and billing as it is capable of storing, updating and analyzing all spatial and non-spatial data, which can be easily shared and reviewed by all the participants. This model can serve as an integrated system for monitoring and controlling the budget, the project activities, updating the progress, Maintaining Material inventory, Project documents, cashflow, Error free Bill verification and certification, Auditing, Handing-over and closures.

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AUTHORS PROFILE



Pranav A. Andhyal
Department: Civil Engineering
Email: pranav.andhyal@gmail.com
College Name: Pillai HOC College of Engineering and Technology, Rasayani, Panvel, Maharashtra.
Mobile No. 8652245922

Education:

- M.E. (Pursuing): Construction Engineering and Management. Mumbai University
- B.E. 2015: Mumbai University in Civil Engineering

Research Undertaken:

- Feasibility analysis by using GFRG Panels for construction.

Experience

- Having about 5 years' experience in execution works, Currently working as a Senior Engineer (QS and Billing)
- Workshop and Seminar Attended
 - Attended one-week STTP on "Infrastructure Development, Possibilities and Challenges" Dated:25/05/2020 to 29/05/2020.
 - Attended Webinar on "Futuristic Engineering" Dated:13/05/2020.
 - Attended one-week online Student Development Program on "Quantum Geographic Information System (QGIS)" Dated:01/06/2020 to 05/06/2020.

Area of Interest

Construction Management, Contracts, Billing, QS, BBS, .



Mr. Karthik Nagarajan
Associate Professor
(PG & UG Guide), Department of Civil Engineering, Civil Engineering Department, Pillai HOC College of Engineering & Technology, Rasayani
ISRO Network Institute Coordinator
Pillai ISRO Outreach Network Institute

Secretary

Mumbai Chapter, Indian Society of Remote Sensing

Achievements

Annual Award -2018 *Best Network Institute Coordinator Award for Contribution towards promoting Geospatial Technology and its applications in Year 2018 IIRS, Indian Space Research Organization (ISRO)*
1st Prize in Maharashtra State Level
in 14th Avishkar Inter-Collegiate / Institute / Department Avishkar Research Convention (AY- 2019-20) – Maharashtra State Level PhD Research by University of Mumbai
Silver in Final District Level
in 14th Avishkar Inter-Collegiate / Institute / Department Avishkar Research Convention (AY- 2019-20) – Maharashtra State Level PhD Research by University of Mumbai.

Qualification

Pursing Ph.D. (Civil Engineering)- Water Resources with application of Remote sensing and GIS.

M.E. Civil (Structural Engineering), B.E. Civil Engineering.

Areas of Interest

Areas of Interest are Remote Sensing, GIS, Water resources, Structural Engineering etc.

Life Time Membership

ISTE, ISH, ISRS, IAHS, IWWA, IAHR, ISG



Mr. Raju Narwade
Head of Department & Associate Professor
(PG & UG Guide), Department of Civil Engineering, Civil Engineering Department, Pillai HOC College of Engineering & Technology, Rasayani

Qualification

Pursing Ph.D. (Civil Engineering)- Water Resources with application of Remote sensing and GIS.

M.E. Civil (Structural Engineering), B.E. Civil Engineering.

Treasure

Mumbai Chapter, Indian Society of Remote Sensing

Departmental advisor of Students' Chapter

Association of Structural Rehabilitation (ASTR)

Areas of Interest

Areas of Interest are Remote Sensing, GIS, Water resources, Structural Engineering etc.