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Application of BIM for Underground Parking Station

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ABSTRACT
Underground parking lots should be carefully planned, built, and maintained as vital large-scale infrastructure that reduces traffic on the busy urban surface. Building Information Management (BIM) is a precise 3D model-based method that equips professionals in architecture, engineering, and construction (AEC) with the information and outputs they need to more effectively plan, design, build, and maintain structures and infrastructure. In order to convert 3D parametric structural geometry models, it is necessary to use an indirect method. However, an automatic pre-treatment and analysis framework that can also realize automatic pre-treatment for mechanical properties, electrical fitments, plumbing fixtures, and ventilation must also be realized. In this research, a 3D model of an underground parking station using the BIM system has been proposed, which in turn can reduce the cost of construction, the total construction time, and errors and clashes during the construction phase. Automated construction processes using BIM tools such as Revit, Navisworks, and MSP can lead to precise and timely completion of projects, especially in the case of underground structures, which are difficult to execute due to various constraints during construction.
Keywords-Building Information Modelling, Underground parking structure, Revit, Navis-works, MSP, project Planning

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I. INTRODUCTION

The Building Information Modelling (BIM) system of interrelated rules, processes, and technology is referred to as a "methodology to manage the essential building design and project data in digital format throughout the building's life-cycle". In order to execute the project on time and within budget, contractors play a critical role in the project lifecycle. This project will demonstrate how BIM technology will help contractors, engineers, and architects with planning, costing, and estimation. It starts with a broad overview of BIM technology and how it differs from conventional CAD (computer-aided design) approaches before moving on to an assessment of BIM tools. The usage of scheduling and cost estimation in BIM is then explained, and a case study is provided to demonstrate how BIM may benefit architects, engineers, and contractors. Building information modelling (BIM) is a developing technology in the architectural, engineering, and construction (AEC) industries. In addition to providing users with accurate and consistent data and information about projects and buildings, BIM technology also enables the tasks necessary to model the building and provides a virtual view of it. Building information models are increasingly being used by a wide range of stakeholders for a variety of reasons throughout the various stages of the project and building lifecycle.

1.1 The scientific definition of BIM

The United States National BIM Standard for BIM is defined as follows:
(1) BIM is a facility (construction) of the physical and functional characteristics of digital expression; (2) BIM is a shared knowledge resource that allows information about this building to be shared in order to create a solid foundation for its setup throughout the facility's entire life cycle, from construction to dismantling; (3) The stakeholders utilize BIM to enter, remove, update, and alter information at various stages of the project in order to support and reflect their separate roles in the collaborative effort. [1]

1.2. BIM Process & Tools

Building information modelling, or BIM, is the process of developing and maintaining the information for a construction project throughout its life cycle. The digital computer model that was made utilizing the BIM process contains all of the structural and functional components of the building. The BIM method produces an information container that is dynamic and transdisciplinary in addition to a visual depiction of the building. The BIM process fosters information interchange and enables a digital depiction of the whole life cycle of infrastructure and buildings, from planning to refurbishment. Each professional must use their own BIM authoring tool to complete their portion of the design discipline according to the BIM process' operational procedures. Professionals are then able to exchange files using the IFC format with-out losing any information thanks to the BIM approach. A single model that incorporate-rates all the data from the numerous disciplines involved is the end product. Building information modelling, or BIM, is the process of developing and maintaining the information for a construction project throughout its life cycle. The digital computer model that was made utilizing the BIM process contains all of the structural and functional components of the building. The BIM method produces an information container that is dynamic and transdisciplinary, in addition to a visual depiction of the building. The BIM process fosters information interchange and enables a digital depiction of the whole life cycle of infrastructure and buildings, from planning to refurbishment. Each professional must use their own BIM authoring tool to complete their portion of the design discipline according to the BIM process' operational procedures. Professionals are then able to exchange files using the IFC format without losing any information, thanks to the BIM approach. A single model that incorporate-rates all the data from the numerous disciplines involved is the end product.

This collaborative BIM process management achieves significant benefits in terms of control and management of an asset during its full life cycle by enabling a seam-less transfer of information. The BIM method is a true advancement in the AEC industry since it enables all parties (architects, engineers, and contractors) to collabo-rate quickly and effectively on a single model, saving both time and money. You may manage a project using the BIM method, from planning through maintenance. When designing using the BIM approach, a model is created that is not just a 3D representation but also a dynamic, multidisciplinary representation that can be used for the duration of the project's life cycle. Due to this, when discussing the BIM process, we do not stop at the third dimension; rather, we discuss all seven of the BIM dimensions, which are shown in Figure 1.

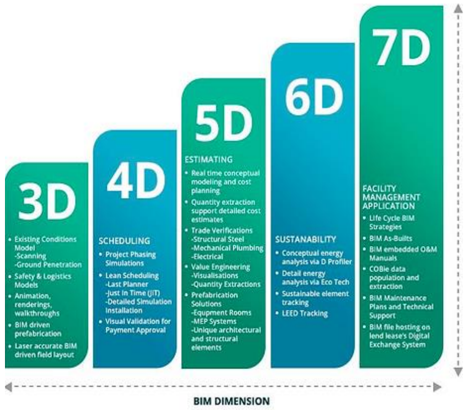

Fig. 1. BIM Dimensions

II. BIM IN UNDERGROUND STRUCTURES

On above-ground structures and infrastructure, a lot of data and information is available. To monitor such constructions and environmental conditions, for instance, it is possible to do visual inspections and connect wireless sensors. [2] The information and data on subterranean environments, such as the groundwater, geology, and existing buried infrastructure, such as pipelines (type, position, and condition), are lacking. This lack of knowledge can have a significant influence on construction projects to maintain, repair, upgrade, and install new buried infrastructure as well as on future planning inside urban underground area. Additionally, the subterranean environment is frequently chaotic in nature. Additionally, the paths and state of subterranean infrastructure are typically hidden. These facts can be linked to the historical absence of subsurface space usage planning and regulation. [3]

These days, many new structures come with an as-built model that includes all the structural and construction details. However, the majority of BIMs don't include any details about the underground infrastructure or the underlying ground conditions close to the building. Consequently, better planning and engineering risk analyses would be possible with a BIM for underground applications (referred to as "BIM for the Underground" in this study), which comprises data on both above- and below-ground infrastructure. Once data has been incorporated into the BIM for the sub-surface system, it may be used more dynamically, i.e., supplied to other programmes or specialized software (such Sketch Up or Revit software to carry out particular analysis). The modified data (or interpreted information) can then be returned to the BIM environment for visualization and future use. [4]

III. PAST RESEARCH

Yi He et al. (2017) investigated how building information modelling (BIM) may be extensively used throughout an architectural project's design. In order to handle transdisciplinary challenges, a feasible strategy based on BIM models was established by combining the design information from numerous sources, partners, and project stages. Their study has put forth a brand-new approach and workflow to assess and examine the performance of the semi-underground designs in a number of different areas. By utilizing current tools, a workable approach based on BIM models is created that aids in resolving interdisciplinary difficulties by combining design data from many sources, collaborators, and project stages. Although the technology used may not be state-of-the-art, it is effective enough to address issues. Additionally, by utilizing a parametric performance analysis, their study has established a different method for completing architecture design, sustainable design, structure design, and equipment design. [5]

Samir Abdelfatah et al. (2020) explained value engineering techniques using a case study for the Greater Cairo Metro (Line 3-Phase 3), and this method has carried out an analysis to get the ultimate optimization. Using the Greater Cairo Metro (Line 3-Phase 3) as a case study and applying the VE technique, they came to the conclusion that cost savings of 23% of the overall cost of typical slabs and 1.7% of the total contract amount could be achieved without sacrificing the essential functionalities of the products. BIM implementation benefits the construction industry as well. These benefits include: visual data retrieval for building projects; straightforward conflict resolution; assistance with scheduling the project's process; maintenance to meet complex costs; and improved organization and well management. [6]

Negar HabibiLasiby (2021) evaluated BIM technology in underground project management processes through a comprehensive review of research background, questionnaire preparation, and interviews with experts. Ten experts who are specialists in this sector made up the statistical population of this study. In their investigation, sampling is non-random and intentional, utilizing ANP, and Super Decisions software is used to analyze the data. Based on an analysis of the study's findings, BIM was found to be more significant than other indicators in the areas of quality management, human resource management, integration management, and cost management. In all five of the project management procedures, the use of this technology is crucial. [7]

ZhanPing Song et al. (2019) emphasized the fundamental tenets and procedures for using BIM technology in tunnel engineering. The initial design concept for the BIM-based collective management platform for tunnel engineering was also provided, and a detailed examination of the platform's viability was done. The Tianjin Metro Line 6 and Tunnel 1 in Yinxi Railway Huanxian County both used BIM. These projects provide supplemental technical tools for addressing actual engineering problems and act as a kind of reference for upcoming application research studies using BIM-like technology in tunnel engineering. [8]

Sheng-Yu Song et al. (2021) proposed a semi-automatic BIM-to-FEA conversion method based on Revit Dynamo and OpenSees software for underground structure construction simulation. The implementation of the strategy happened in three steps. The first step was to generate parameterized BIM models using popular tube stations as the research subjects. Second, an automated BIM-to-FEA conversion technique was created to perform FEA calculations. It is built using tool command language scripts and Dynamo visual programming. Then, the approach was broadened to in-corporate construction simulation. Based on the BIM model of the station's enclosing structure, an automatic FEA model of the diaphragm wall was built with a variety of working conditions, and a structural simulation of the open-cut excavation process was completed. In addition to creating a time-saving building simulation framework based on BIM technology, this method includes an automatic BIM-to-FEA conversion mechanism that can quickly generate FEA construction simulation models with a variety of working conditions. [9]

Yugandhara R. Khasbage and Swati Kshirsagar (2022) investigated how this clash detection method may be used in conjunction with BIM coordination to mini-mize conflicts during the construction of a specific building. They used G+3 residential buildings, which are made up of BIM models for the architecture, structural engineering, and mechanical, electrical, and plumbing (MEP) systems. They employed commercial tools like Autodesk Navisworks Manage 2022 and Autodesk Revit 2021 for their following clash detection investigation. Additionally, they focused on methods to standardize and simplify the Autodesk Navisworks clash detection process. The project's total cost won't go up, and overruns are prevented by finishing on schedule and within budget. They came to the conclusion that savings for G+3 apartment complexes could only be made up to about 1% during the design stage. However, when this model is used during real-time construction, more time and money can be saved. [10]

IV. ANALYTICAL STUDY AND RESULTS

For analytical purpose, we have considered 3 story underground parking building with 5m floor to floor height. Building has been designed structurally in ETABS software and then BIM model has been created using structural and architectural design data. Plan dimension of the building 80 feet X 140feet with 20 feet bay spacing. Floor to floor height of the building is 5m. Plan of building in ETABS has been shown in figure 2.

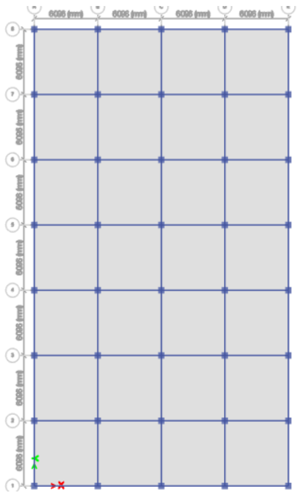

Fig. 2. Plan of building in ETABS

4.1. Project Visualization in Preconstruction

Pre-construction sets out the whole scope of work and timeframe for completing the projects for the team and client during the first stage of construction projects. In the first stage of the project, planning and coordination are finished before the actual construction. Since problems and adjustments must first be reviewed and then accepted by the stakeholders, the pre-construction phase takes a long time to complete. It takes time to study the drawings in order to verify all the architectural designs and plans. In order to minimize additional costs or rework that causes a delay, problems like constructability and BIM coordination services have been resolved with the use of a 3D BIM model. It helps create a solid line of communication between the project team members. In the project's pre-construction stage, BIM can kick off visualization and communication among many disciplines. Some of the 3D models made during the pre-construction stage are shown in Figure 3.

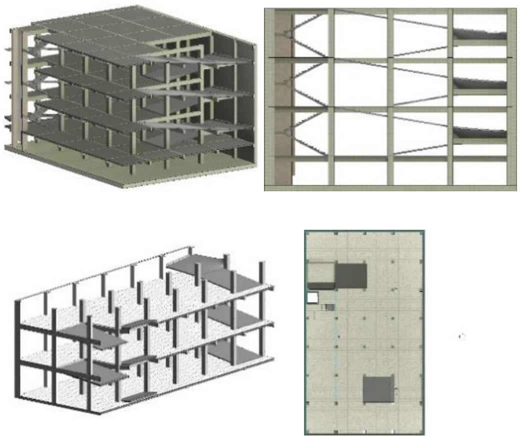

Fig.3. Pre-construction stage 3d view, sectional view and plan view using BIM

4.2. Quantity Estimation

Quantity estimation is the process used to establish the quantities and lay out the steps needed to complete the task before it is completed. Errors are frequently made because designing is frequently perceived as a time-consuming process that also entails manual labor and repeated chores. Quantity takeoff software was available before BIM technology. The majority of their aid was devoted to figuring out how to organize and account for items and processes more quickly by conducting simple mathematical calculations. Thanks to BIM technology, both the sharing of information that is useful for construction and the computation process have experienced substantial improvements. However, this shows that the 3D BIM model was made with great care and complies with the specifications for producing an accurate cost estimate.

We simply choose a wall, a window, or a slab to read all the data and characteristics for a building's 3D BIM model. As a result, the BIM model is designed as a data store that can be consulted as well as used throughout time. If the quantity takeoff is taken from the BIM model rather than from the 2D drawings, the measurements are directly produced from the 3D model without the possibility of error and are always compatible with the project. Additionally, every adjustment made (for example, if you decide to change the size of a window) is seamlessly and immediately updated on all the papers (plans, sections, cost estimates, time schedules, etc.). Human error as well as cost estimate processing time have been greatly cut. This unique technique does not call into question the competence of those who participated in the planning of quantity takeoffs. It is crucial to avoid repetitive and mechanical procedures in order to free up more time for design details, risk assessment, construction phases and methods, and any other aspects that are relevant to providing an accurate and fair cost estimate. Figure 4 displays the results of the amount estimation in BIM using the Revit model.

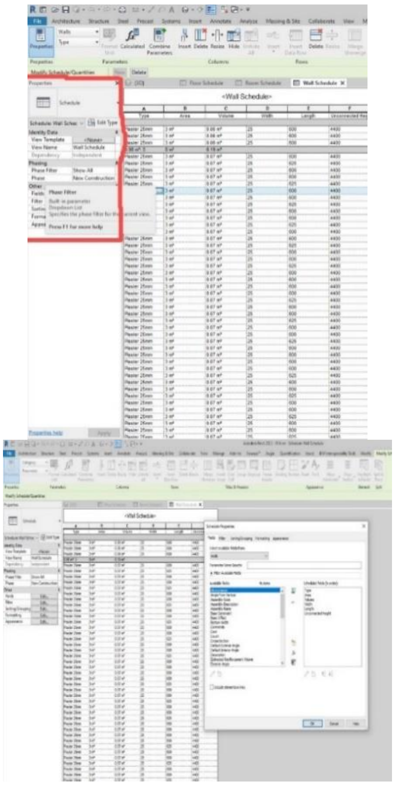

Fig.4. Output in Revit for quantity estimation elements

Architectural quantity estimation

BIM process software like Revit directly estimates the quantity of all architectural elements like walls, plaster, flooring, tiles, etc. from the 3D model, and any changes in the plan or elevation of the project will automatically change the quantities, and we can get the final estimation in terms of spread sheets. In our study, we considered a 3-story underground parking station for estimation, and the results are shown in Table 1 and Figure 5 below:

Table 1. Quantity estimation of architectural elements

Element	Concrete Quantity (m^3)
Plaster	37.92
Tile	136.70

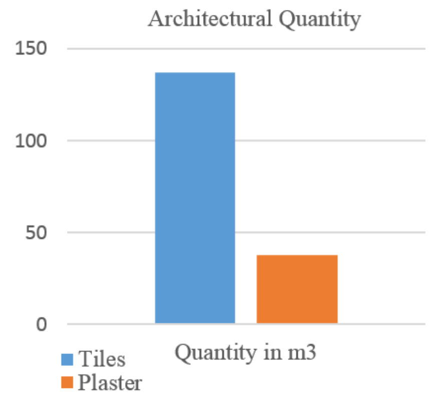

Fig. 5. Quantity estimation of architectural elements

Structural quantity estimation

Structural elements have been modelled as per the structural drawings using Revit Structure. The thickness of the slab is 200 mm, and columns and beam sizes are as per design. Retaining walls thickness is 450mm. Steel and concrete quantities are derived directly from the 3D model. Any changes in design parts can be easily incorporated into the structural model in Revit, and quantities of steel and concrete will change accordingly. Quantity estimation of structural elements has been shown in tables 2 and 3 and figures 6 and 7.

Table 2. Quantity estimation of Concrete

Element	Concrete
R.C.C. Walls	1165.59
Column	6.48
Beams	271
Slab	579.79
Foundation	686.01
Ramp	283.14

Table 3. Quantity estimation of Steel

Element	Steel Quantity (kg)
R.C.C. Walls	42354
Column	45786

Beams	25385
Slab	67171
Foundation	17129
Ramp	13701

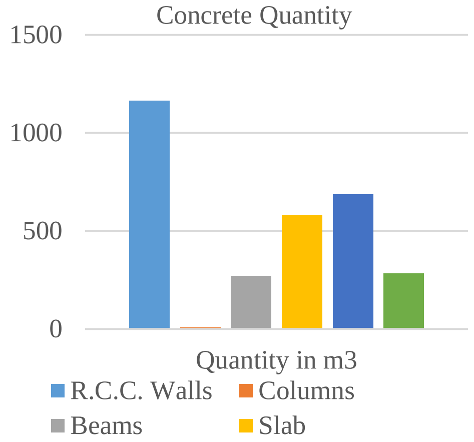

Fig.6. Concrete Quantity estimation of structural elements

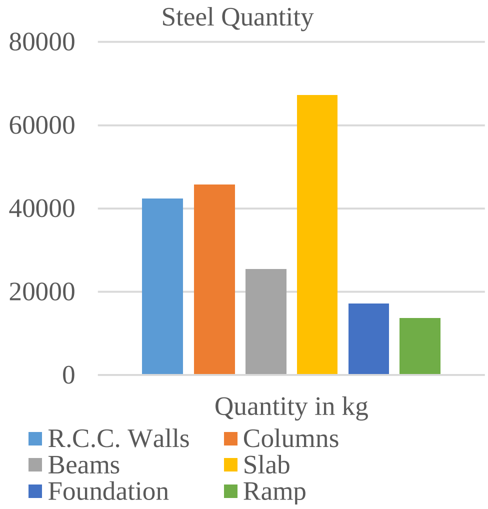

Fig.7. Steel Quantity estimation of structural elements

4.3. Clash Detection

Clash detection is an essential phase in the integrated BIM modelling process. Building a comprehensive master model including design models from several engineering design disciplines is required for BIM modelling. Navisworks, the best BIM-adopted software now on the market, is useful for collision detection and clash report creation. Clash detection is utilized once all the models have been incorporated into the BIM modelling process. By assisting architects and contractors in reducing the likelihood of multi-level design changes, which can result in budget overruns and a delay in project completion time, clash detection through Building Information Modelling (BIM) helps speed up projects. This is done by identifying conflicts between multiple models during the design phase. Navisworks was used to find some clashes in our building that were later eliminated from the final BIM model and GFC drawings. Some clashes between beam columns and walls are shown in Figure 8.

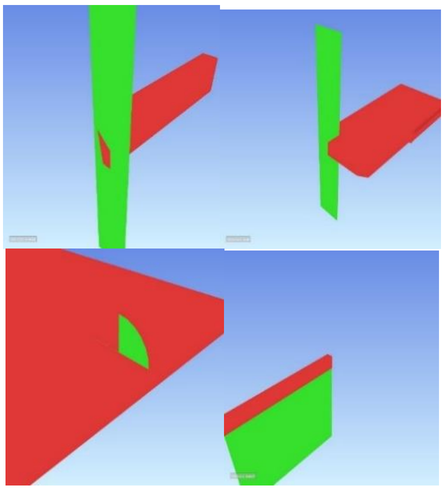
Fig.8. Clash detection using Navisworks

4.4. Project Scheduling and Planning

Building information modelling, or BIM, is a technique that has Building information modelling, or BIM, is a technique that has fundamentally altered how construction projects are planned and executed. Construction managers can create a virtual project model that can be reviewed and modified before any actual work is done. As a result, estimates are more precise, the finished product is better, and there are less construction-related surprises. Construction managers can visualize the project, identify potential problems, and even keep tabs on how the work is progressing on the ground by using building information models (BIM). First, using BIM software, a three-dimensional virtual building model is created. This approach can be used for complex project planning and management in the construction industry. Using BIM, construction managers can communicate with other project team members including architects and engineers. Together, we can ensure that the project is completed on time and within budget. BIM can also be used to train new employees and provide owners or clients with the last-minute handover information.

The BIM model can be integrated with project management software like MSP, and its data can be loaded right into the BIM model. Figure 9 depicts the project schedule for the parking station under consideration. The percentage of work completed for each activity was determined by comparing the baseline and actual durations. There are certain activities that are crucial. The actual 3D model can be linked with the entire planning process, allowing work to be finished within the allotted budget and schedule.

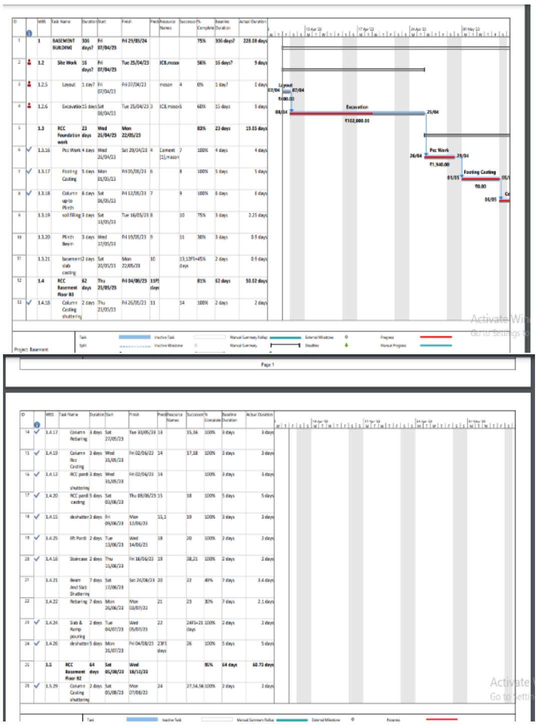

Fig.9. Project Scheduling and planning using MSP linked with BIM model

V. CONCLUSION

After studying the complete BIM process and its tools for a 3-story underground parking station building, we can draw the following conclusions:

• BIM is the most used and powerful tool these days in construction projects because it can relate all required data in a single 5D model.

• For underground structures, uncertainty during construction is a major issue that can be easily solved by using a BIM model.

• Cost estimation and quantity estimation can be done accurately using a 3D BIM model, and as architectural or structural design can change at any stage during construction, by incorporating these changes in the BIM model, quantities will automatically be updated with precision.

• Clashes in drawing are a common problem during the execution of any project, as MEP, structural consultants, and architects work separately for different organizations. By using a single BIM model, these clashes can be easily identified, and drawings can be updated accordingly. Thus, the project can be completed with the utmost accuracy as per the architectural intent.

• Construction planning and scheduling can also be incorporated into BIM by modelling MSP software data in Revit. We can directly link all activities during construction to our BIM model so that accurate time duration and resources required can be identified in advance, any delay in the project can be determined, and the required remedies can be implemented.

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