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Through the use of GIS, a timetable for recurring building projects may be generated, visualized, and evaluated.

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ABSTRACT

The context in which a series of similar building tasks must be completed is crucial. However, it is difficult to account for environmental factors in a created timetable using either the planner's prior experience or the commercially available tools. Therefore, in this investigation, geographic information systems (GIS) are used to think about how the environment impacts the timetable of a recurring building job. The GIS environment is used to create an interactive application for project scheduling, with custom scripting for both repetitive and nonrepetitive tasks. By connecting the timeline of a cyclical project with relevant 3D components, GIS has generated 4D execution sequences together with its surroundings. Therefore, GIS may be used to take into account the impacts of surroundings on the timetable of a recurring building project. The built schedule is further tested for constructability by using the 4D execution sequence and its surrounds. In addition, it aids in the detection of spatial feasibility, constructability analysis, and logical problems in the schedule. As a case study, the created interactive tool is being put to use in the scheduling of the Udaigiri boys hostel (UBH) building, but it will also be of service to practitioners and planners in the scheduling of other similar construction projects.

KEYWORDS; Scheduling in repetitive construction using 4D-GIS, LOB, and CPM

Introduction

Repetitive scheduling refers to the process of planning a construction project with several iterations of the same activities or tasks, such as in high-rise structures, motorways, railways, pipelines, etc. When building, the crew must go from unit to unit, floor to floor, or location to location to complete the same or comparable activities (Sharma and Bansal 2018). Within a repetitive building project, both non-repetitive and repetitive components may show themselves. In a multi-story structure with uniform floor coverings, for instance, the laying of the roof and foundation constitutes non-repetitive units, but the construction of each individual floor is a repeated unit containing repetitive operations. Thus, both types of units are needed for a repeating construction job.

Most non-repetitive building projects are scheduled using the critical path method (CPM) (Fan and Tserng 2006). However, CPM has been criticized for its inability to plan a building project with a high degree of repetition (Russell and Wong 1993). Various strategies have been proposed in the literature for

scheduling of such building projects has been the subject of a number of studies (O'Brien 1975, Birrell 1980, Dressler 1980, Johnston 1981, Arditi and Albulak 1986, Chrzanowski and Johnston 1986, Harmelink 1995, Harris and Ioannou 1998, Harmelink and Rowings 1998, Huang et al. The linear graph is used to represent the schedule of the repetitive construction project for the following reasons: (a) graphical representation of schedule delivers instant information of location of work and progress direction; (b) graphical representation of schedule takes less time and efforts to get generated; and (c) ensures resource continuity and aids in identifying space-time conflicts (Arditi and Albulak 1986; Arditi et al. 2001; Harmelink 2001; Hassanein and Moselhi 2004; Mahdi 2004; Yang and Ioannou 2004; Yang and Chang 2005). Nonetheless, repeating scheduling techniques tend to focus on theoretical research rather than practical application.

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Common approaches to making schedules for repeating projects include linear scheduling (Johnston 1981; Chrzanowski and Johnston 1986), line of balance (Carr and Meyer 1974), repeated scheduling (Harris and Ioannou 1998), and the vertical production technique (O'Brien 1975). Among

From among these techniques, line of balance (LOB) has been around the longest and is the most often used (Arditi and Albulak 1986). With LOB, several locations contributing to the completion of a single task are represented by a single line in the timeline. Thus, the LOB schedule gains one less slot for a comparable, repetitive activity. The CPM approach is inadequate for recurring building projects because it does not ensure the continuation of necessary resources (Sharma et al. 2016). On the other hand, with LOB, resources are kept in a continuous flow. It's simple to rearrange LOB tasks and see how doing so affects the schedule (Ammar and Abdel-Maged 2018). The research suggests integrating CPM and LOB to plan repetitive projects since they account for both repetitive and non-repetitive tasks in building projects (Hegazy and Wassef 2001; Hyari and El-Rayes 2006; Ammar 2013). In this combination, CPM is used to plan one-off tasks, whereas LOB is used for repeating ones.

Scheduling in 4 dimensions using a combination of CPM and line-of-business

The one-dimensional schedule that the combined CPM and LOB-based plan provides details the beginning and ending times of each activity. It's challenging for planners to interpret the order of tasks in a combined CPM and LOB-based schedule. Its meaning is contingent on the project planner's level of familiarity with the subject matter, level of skill, and capacity to conceptualize the execution sequence (Winch and Kelsey 2005; Arditi et al. 2017). As a result of a lack of connection with the graphical/spatial features of a construction project, it might be difficult to reliably picture the execution sequence in one's mind. The existence of several operations in a construction project makes its interpretation more challenging without any relationship between repeated schedule and graphical/spatial components of the project. The combined CPM and LOB-based scheduling also makes it difficult to identify any missing activities or logical errors. Therefore, it is crucial to connect the dots between the spatial/graphical elements and the established timetable.

A construction planner uses a technique known as four-dimensional modeling to visualize the workflow by connecting the various stages of the project's development in three dimensions (Cherneff et al. 1991; Koo and Fischer 2000; Akinci et al. 2002; Perkins and Skitmore 2015). The constructability and build-ability of a CPM-based schedule may be verified with the use of 4D models, and the models can also be used to identify missing activities and logical mistakes (Bansal and Pal, 2007; Pal and Bansal, 2011). With the help of the 4D model, the diverse members of the project team are able to better communicate and work together (Koo and Fischer 2000). However, 4D modeling has not been extensively investigated for the combined CPM and LOB-based scheduling to discover a wide range of issues in the created schedule. Since there are issues with the combined CPM and LOB-based scheduling, it must be linked with 3D elements to produce a 4D execution sequence. In the same way that 4D modeling will help us better comprehend and visualize the execution sequence of a repeated project, it will also improve the way in which such a project is developed in reality (Moon et al., 2014). It has been noted in the literature that several 4D-modeling tools have been created across multiple platforms to integrate 3D components with CPM scheduling (Bansal and Pal 2009). Typically, these programs make use of 3D models retrieved from CAD/BIM-based programs (Khanzadi et al., 2018) and schedules generated in Primavera or Microsoft Project. Scheduling repeated construction projects using a combination of CPM and LOB-based methods has not received much attention from the field of 4D modeling. Thus, a 4D tool for combined CPM and LOB- based scheduling has to be developed.

Integration of CPM with LOB-based scheduling calls for the use of GIS.

The designed schedule's effectiveness on the building site is directly related to taking into account the impact of surrounds (Bansal 2017). When modeling a building's components, CAD and BIM-based technologies cannot account for the impact of the environment on the construction timeline since they don't have the capability to do so. There are several examples in the literature of GIS being used to simulate a building site's environment (Bansal 2011, 2012, 2013, 2015, 2018). Prior research on construction project scheduling on GIS platforms exclusively considered the use of CPM-based tools for scheduling non-repetitive tasks. Only in the case of unique projects will CPM examine logical relationships. But LOB's primary function in recurring building projects is to ensure that resources are available without interruption. As a result, the current study's key contribution is the creation of an integrated CPM and LOB-based scheduling tool for scheduling both non-repetitive and repetitive components of a repetitive construction project, taking into account logical interdependence through CPM and resource continuity via LOB. Python, an open-source programming language, is used in this investigation to create the coordinated time-keeping app. The interoperability issues in the building sector have been mitigated with the use of Python, an open source programming language. Therefore, in order to make the combined CPM and LOB-based schedule implementable, the impacts of existing facilities/utilities, topog- raphy, and surroundings may be taken into account.Using GIS, the repetitive construction schedule

must take into consideration existing facilities/utilities, which provide energy, water, and other facilities (Bansal and Pal 2008). GIS are used to maintain lay- out of electric lines, sewerage network, and water pipelines, which have an important impact on the construction schedule. Usually, the integrated CPM and LOB-based scheduling particularly in hilly areas where topography plays a key role must not neglect surroundings. 4D modelling of the integrated CPM and LOB-based schedule must be done along with its surroundings. Hence, the use of GIS for the inte- grated CPM and LOB-based scheduling, linking 3Dcomponent with the developed schedule, and to model surroundings to consider its effects on the schedule has been explored in the present study.

Goals of the Study

- The primary goal of this investigation was to generate, visualize, and evaluate combined CPM and LOB-based scheduling of a repetitive project using GIS. A 4D execution sequence, including its surroundings, was expected to be generated by linking the activities of the integrated schedule with relevant 3D components in order to verify the efficacy of the designed repetitive building schedule. The goals of this study were attained by means of:

Creating a tool in GIS for combined CPM and LOB-based scheduling such that repetitive units can be scheduled using LOB and non-repetitive units may be scheduled using CPM.

Modelling of the environment in which a building project is being carried out in

GIS and building information modeling (BIM) will be used to produce 3D components that correspond to different activities on the repeating schedule and then connect those components together.

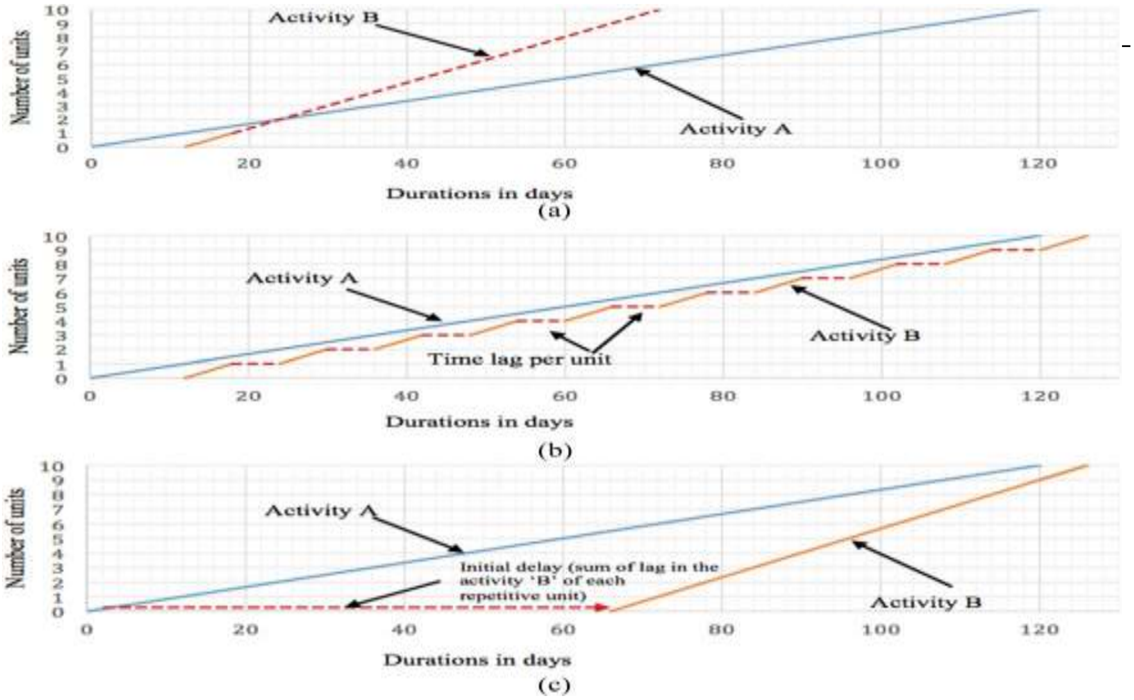
Tool development for scheduling activities that are repeated repeatedly

Instrument for scheduling based on LOBs

When planning the timeline for recurrent building projects, line of balance is the method that is most often recommended. In this method, the repeated tasks are shown as a single line on a graph. This approach is known as "here, in this technique." For instance, if an action 'A' is carried out on ten repetitve units, this will be shown as a single streak in LOB. Figure 1 illustrates two iterative processes, referred to as 'A' and 'B,' each of which has a unique output rate. When it comes to the representation of a LOB-based timetable, the production rate is an extremely important factor. If the production rate of activity 'A' is half that of activity 'B,' then activity 'B' will overtake activity 'A' after the second unit, which is very impossible in practice, as illustrated in Figure 1. (a). As can be seen in Figure 1, a delay has been included into the beginning of each repeated unit's activity "B" so that the interrelationship between the two activities may be kept intact. This delay was implemented for the purpose of maintaining the interrelationship (b). Because of the delay in beginning time of activity 'B,' each repeated unit does not preserve resource continuity, which leads to inefficient use of the available resources. The beginning delay in the commencement of activity 'B', of the first repeated unit, has been supplied for the purpose of preserving the continuity of the resources. As can be seen in Figure 1, this delay is equivalent to the complete lag that exists in each and every unit of 'B' activity (c). Therefore, action 'B' is finished without any interruptions, therefore ensuring the continuity of the resources and the link with the other activities, namely activity 'A'. As a result, in the event that the rate of production of the second activity is higher than the rate of production of the first activity. If the second activity is permitted to begin, it will complete sooner than the first activity, which is something that must be avoided if network logics are to be preserved. As a result, the value of the Earliest Start Time (EST) of the second activity of each repeated unit is computed by using the greatest value calculated for the difference between the EST of the current activity and the EST of the activity that came before it. In order to determine the EST for the present undertaking, its duration has been added to the amount of difference that is greatest. The following equation was established in order to calculate the updated EST of the activity that is being done in the first unit:

$$EST^{1}_{-k} = EFT_{i-j} + t_{j-k}$$

Together with its matching operations in the built combined CPM and LOB-based schedule in order to generate a 4D execution sequence.$R\ j$



$$\max_{1}^{n} \quad EST_{j-k} \quad EST_{i-j}$$

(1)

surroundings; making sure the suggested timetable can be carried out while keeping the project's surroundings in mind; the environment in which the project is being evaluated as an option.

The aforementioned equation had a role in the development of the device in question.

The methodology that was utilized in this investigation was expanded, and the formula that ought to be used in circumstances in which the production rate of an earlier activity turns out to be lower is as follows:

Figure 1. The following is a graphical depiction of the LOB concept: (a) after the second repeating unit, activity "B" crosses activity "A," which is not achievable in practice; (b) a delay in the beginning time of activity B, of each repetitive unit, has been supplied; (c) an initial delay in start of the activity B of, first repetitive unit, has been provided.

$$EST^{n}_{R\ j-k} \;¼\; EST^{n-1}_{R\ j-k} \;þ\; t_{j-k} \qquad (2)$$

ESTi–j

represent the EST for the action that came before, and n is the total number of floors or units that are repetitious.

The equation used for calculating the EST of current activity, for the first unit, is given as:

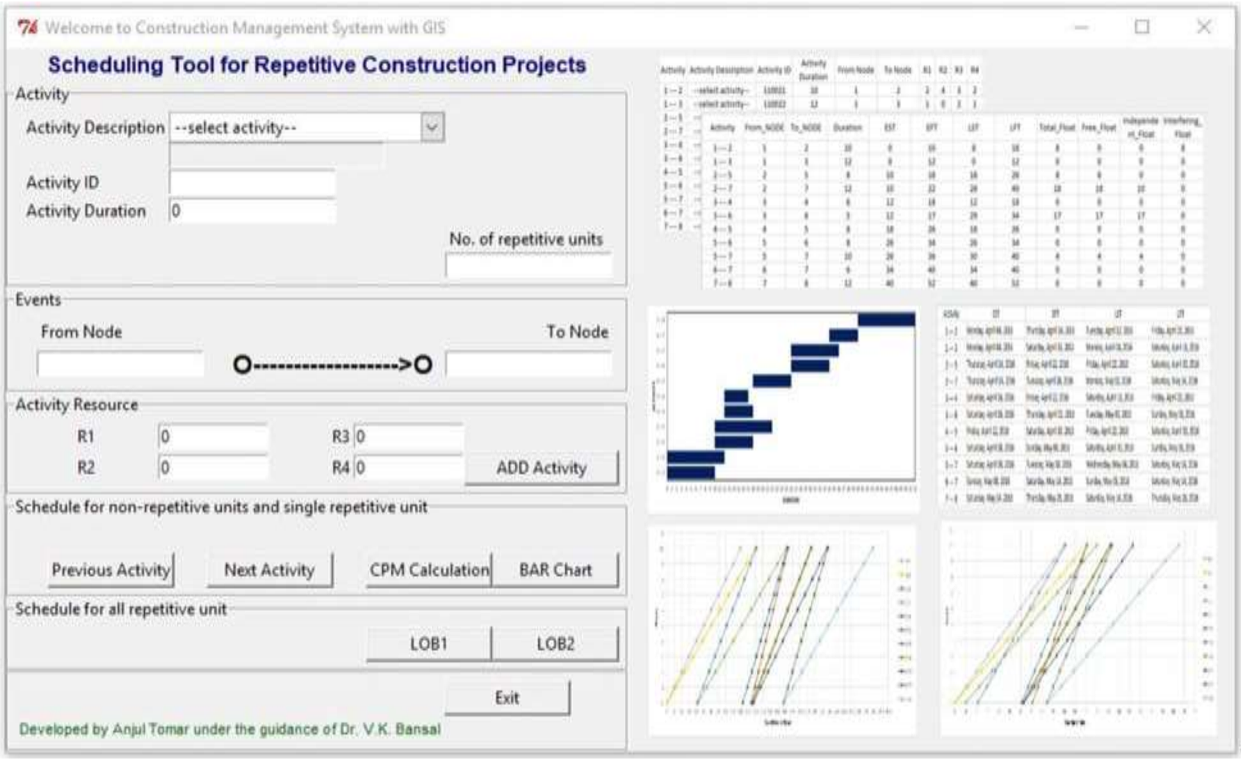


Figure 2. GUI of scheduling tool for non-repetitive and repetitive units.

associated with a building or construction project. A user may choose an activity from the list; however, if the needed activity is not included in the list, it may be added as a new activity by choosing the 'other' option. The choices under "Activity ID," "Activity Duration," and "No. of repeating units" make it possible for a user to specify the identifier of an activity as well as its duration and the total number of repetitive units. In the Events section, there are two text boxes labeled 'From Node' and 'To Node,' which are used to input the tail and head event numbers for an activity. The Activity Resource section has four boxes labeled "R1," "R2," "R3," and "R4," which are designed to make it easier for the user to enter the different kinds of resources that are necessary to carry out an activity. Clicking the 'ADD Activity' option allows a user to add information relating to the subsequent activity once they have finished entering the pertinent details of the previous activity. It is done again and over again until the last activity of a project has been entered. Within the next section, which is labeled "Schedule for non-repetitive units and single repetitive unit," there are four buttons that read, respectively, "Previous Activity," "Next Activity," "CPM Calculation," and "BAR Chart." The 'Previous Activity' button makes it easier for a user to discover specifics on the activity that came before it. The 'Next Activity' button displays information on the activity that will occur next. By clicking on the 'CPM Calculation' button in the tabular form, a user may construct the schedule for either non-repetitive units or a single repetitive unit. It is comprised of a total of twelve columns, which are as follows: Activity, From Node, To Node, Duration, Earliest Start Time (EST), Earliest Finish Time (EFT), Latest Start Time (LST), Latest Finish Time (LFT), Total Float, Free Float, Independent Float, and Interfering Float. In addition, a user may plot a bar chart by clicking on the icon labeled "BAR Chart." The next section provides an easier way to generate the timetable for all of the repeating units. It has two buttons labeled 'LOB1' and 'LOB2' in its layout. The 'LOB 1' button makes it easier for a user to construct a timetable for all repeating units in which resources are restricted but time is not a factor in the decision-making process. Alternatively, using the "LOB 2" button will generate the schedule for all repeating units in which time is a restriction but resources are not. An example of the interface of the tool that was built to schedule repeating units is shown in Figure 3. On the right-hand side of the window, thumbnail representations of the output in the form of tables and graphs are shown. The findings are kept in a.csv file format for storage. At the very bottom of the graphical user interface is a button labeled "Exit," which may be used to terminate the program once it has been used. Readers interested in further information about the instrument should refer to the research by (Tomar and Bansal 2019)

Techniques for the formulation, representation, and analysis of an execution schedule

The technique for the development, visualization, and assessment of an executable schedule has been created and is illustrated in Figure 4. This will allow for the generation of an executable schedule. It illustrates the step-by-step process that was carried out in GIS in order to build the execution sequence of the combined CPM and LOB-based

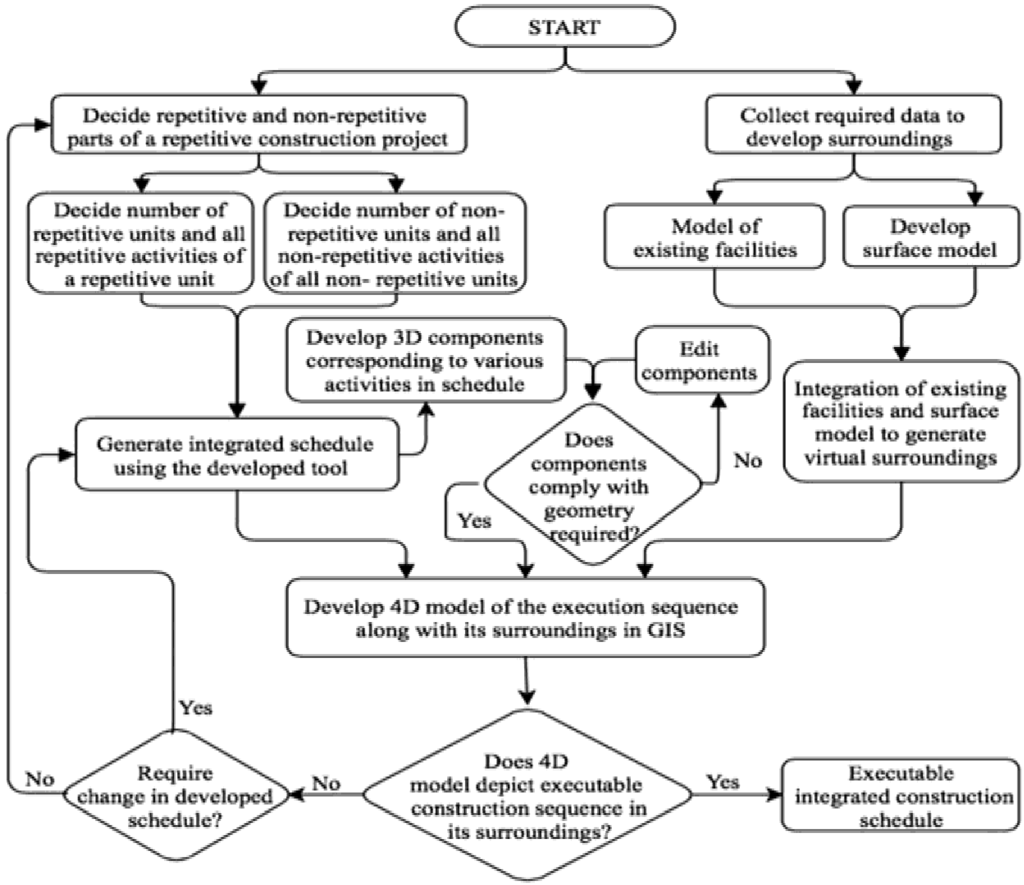
Figure 3. GUI of scheduling tool for repetitive units.

schedule along with its surroundings. Different stages involved in this are discussed below:

In a project that involves repetition, choosing between repetitive and non-repetitive components.

A repetitive construction project is divided into repetitive and non-repetitive parts at the initial level of the project. At the second level, a construction project's repetitive component is broken down into a certain number of repetitive units, while the non-repetitive component is broken down into a certain number of non-repetitive units. At the third level, a repetitive unit is broken down into a number of different activities, and each non-repetitive unit is similarly broken down into a number of separate activities. Figure 5 presents the work breakdown structure that was used for this particular research endeavor. At this point, any and all conceivable repetitive and non-repetitive actions of repetitive and non-repetitive units are tallied up and accounted for. Networks are used to organize both the repetitive actions that take place inside a repetitive unit and the non-repetitive activities that take place within all non-repetitive units.

Arrangement of both non-repetitive and repetitive components in the schedule



The length of time spent on each activity that belongs to a repetitive unit as well as each non-repetitive unit has already been determined. If a project contains four non-repetitive units in addition to the number of repetitive units that it has, then the project has a total of five networks: four networks for the non-repetitive units and one network for the repetitive units combined. The detected activities, their durations, and their interdependencies are obtained as input by a CPM-based Python script that is built for the purpose of scheduling non-repetitive units. The output of the newly designed tool is in the form of a tabular document, and it includes EST, EFT, LST, and LFT, as well as a variety of floats for each activity. Additionally, the timetable might be offered in the form of calendar dates as well. The detected activities, their durations, and the interdependencies between them are obtained as input by a LOB-based Python script that was created for scheduling repeating units. The output of the created tool is in the form of graphical and tabular representations, each of which contains the start and completion times of each activity, for each and every repeated unit. In addition to this, the calendar dates of the beginning and ending times of each activity are also produced.

Figure 4. Procedure for generation, visualization, and evaluation of integrated CPM and LOB-based schedule.

Development of 3D components in BIM

BIM is used to construct 3D components that correspond to activities that take place in both repetitive and non-repetitive units. It is not essential to include three-dimensional components for every item on the agenda. Activities such as leveling a building site and curing concrete, for instance, are not allowed to include linked 3D components. Checking the geometry of the newly generated components is done so in accordance with the specifications of a project. In order to generate the execution sequence, we make use of the components that are associated with each activity in the schedule. The whole set of components is brought over to GIS in the form of layers.

Linking schedule with 3D components

On an EST or LST basis, the relevant activities of the timetable are connected with the appropriate 3D components. Linking is accomplished by using a Python script that was designed specifically for this purpose and running it in ArcGIS. The script adds a field to the attribute table of each component and the produced schedule that is titled "Activity Description" or "Activity ID." This is an important column to fill out in the "attribute table" of each component, as well as the schedule that was produced, so that the connection may be made. There should not be any duplicate entries in either the 'Activity Description' or the 'Activity ID' fields. The connection between the activities on the schedule and each of the 3D components results in the creation of a 4D model, which makes it possible to quickly perceive whether or not the developed schedule is comprehensive and accurate..

Development of surroundings

When developing an executable construction schedule for a repetitive construction project, both the construction process itself and its surroundings are taken into consideration from a variety of perspectives. These perspectives include the following: available services, logistics, construction materials to be procured, storage space for materials, topography, and so on. This guarantees that the building schedule may be adhered to in the appropriate manner (Bansal 2015). Because of this, the environment has to be modeled so that we can determine how the surrounding environment will have an influence on the timeline that we build. This will allow us to take into account how the surrounding environment will have an effect. The

The modeling of the surrounding area is broken up into two distinct phases: the first phase models the surface, while the second phase models the existing infrastructure and utilities. The existing material resources that are found in the area around a building are referred to as its surrounds, and they may have an effect on the construction schedule if they are present. The key components of the environment that surrounds the site are its topography, its accessibility and road network, the water supply network, the availability of materials, the positioning of energy resources, and other characteristics. The topography of the location is the single most important component that plays a role in determining the schedule for the construction project. For instance, the same style of structure that is being erected in hilly regions and plain areas may have distinct execution timetables due to the varying topographies of the two places. This is because mountains and plains have quite different elevation profiles. When developing a site, it's possible that areas with a large slope would need more extensive cutting and filling than flat portions. The tough topography of the site may make construction more challenging, have a negative influence on the working environment and the productivity of various site operations, and have an impact on the schedule. All of these factors may be affected by the topography. Readers who are in need of further information on the modeling of their settings are encouraged to review the research conducted by Bansal (2015).

Development of execution sequence along withsurroundings

The 4D execution sequence that was developed is then put in its surrounds in order to see its engagement in its neighborhood. An essential asset for a planner to consider while doing a schedule review is a 4D execution sequence that includes its surroundings. It is critical to determine if the constructed 4D model accurately shows the building process in relation to its surroundings, since this is an essential consideration. The produced schedule is only considered definitive if the execution sequence can be deemed satisfactory; in the event that it cannot, the schedule is updated once again, as shown in Figure 4.

Schedule evaluation

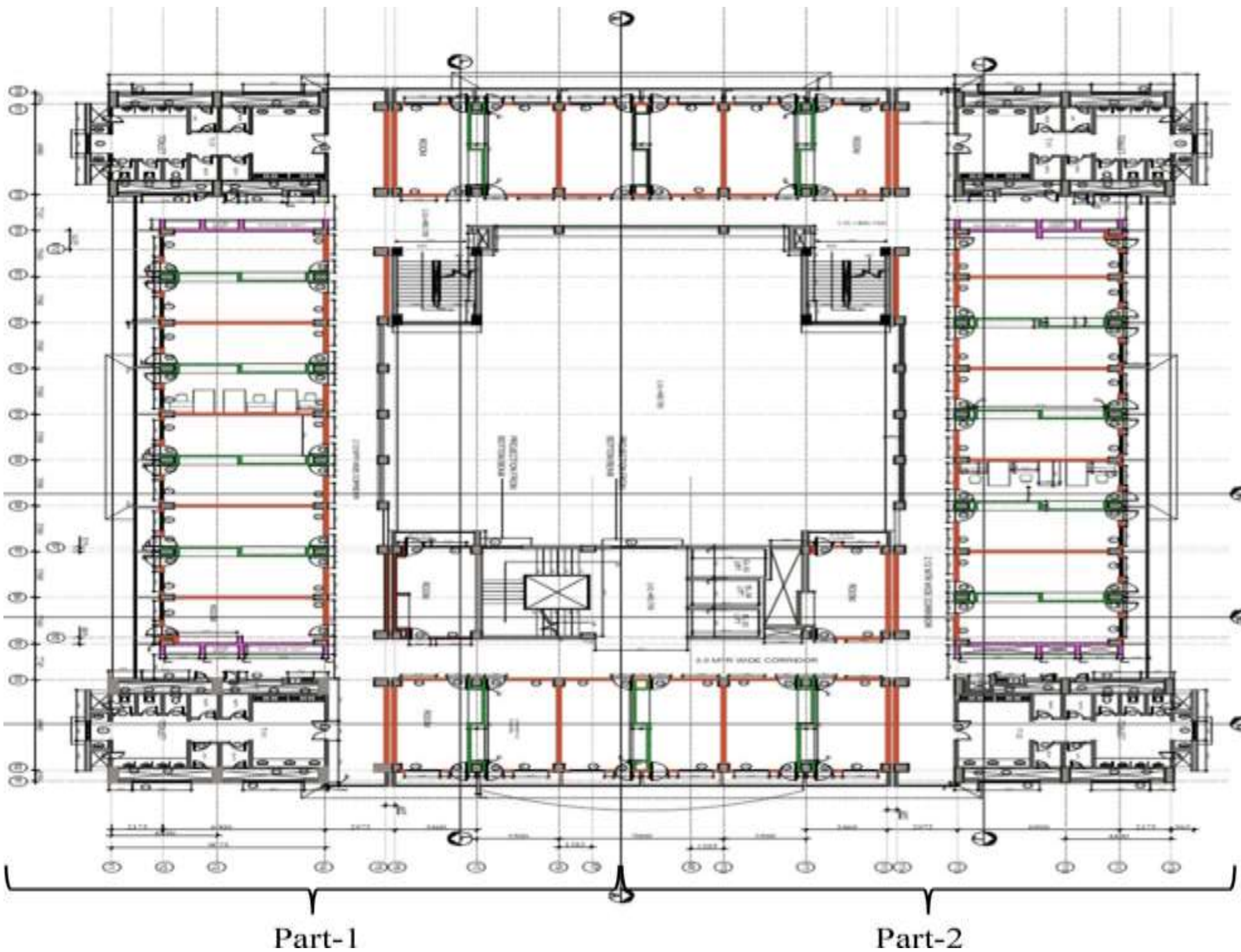
The evaluation of the developed schedule of a repeti- tive construction project is done through 4D execu- tion sequence along with its surroundings. Mainly, 4D execution sequence is used to evaluate the devel- oped schedule of a specific construction project for its constructability/executability on a specified location. Also, the schedule is evaluated using 4D execution sequence by identifying logical errors in a repetitive unit of a repetitive construction project, missing activ- ities in the repetitive schedule, and spatial feasibility of a repetitive construction project on the speci- fied location.

Implementation of the developed tool

Description of the case study

The pattern of building at the Udaigiri boys hostel at the National Institute of Technology (NIT), which is situated in Hamirpur, India, has been used as the basis for this case study. The roughly 178-acre campus that is home to one of India's most prestigious technical colleges, the National Institute of Technology (NIT) Hamirpur, is located amid mountainous terrain. The highest possible value of the

Figure 6. **Architectural plan of floors number 3 to 7 of the hostel building.**



The various pieces of the campus's infrastructure have been built in the most advantageous positions. In these modern times, new infrastructure is being built in low-lying areas to accommodate the expanding number of academic and non-academic pursuits. As a result, the topography of the location where the new buildings are being up on campus is playing a crucial part in the construction design for those structures. The building used for the case study is a reinforced cement concrete framed structure with an estimated construction cost of roughly 3.7 million dollars in the United States. From the third to the seventh level, it is made up of five identical floors in their entirety. Figure 6 illustrates how each level is subdivided into two pieces. These two portions of each floor were each intended to function as their own independent repeating unit, bringing the total number of repeated units over all five floors to 10.

The building site is situated in a mountainous region and is messy to look at. In order to preserve the natural topography of the area, two additional floors, numbered 1 and 2, have been built to the front side of the building. The architectural design for these two storeys is unique compared to that of the other five floors. These two floors have been analyzed and accounted for as two separate non-repetitive units. The footprint of the building under consideration for this case study looks to be in the shape of three steps, with the first level resting on the first step, the second storey resting on the next two steps, and the third floor resting on all three steps. The case study building gives the appearance of having seven levels when seen from the front, but when viewed from the rear, it gives the impression of having just five floors. The building information modeling (BIM) program Revit Architecture was used to create three-dimensional components that correspond to different tasks in the planned schedule of the case study project..

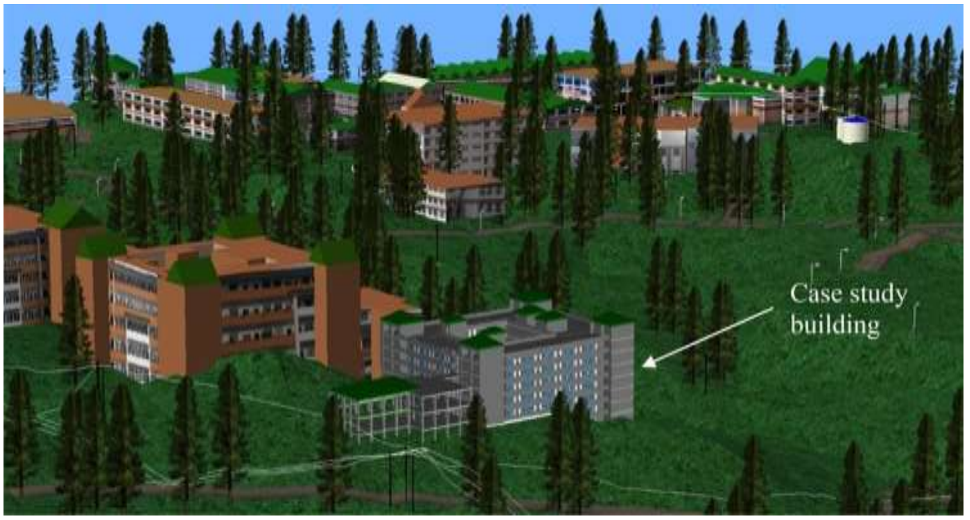


Figure 7. Virtual 3D model of the hostel building along with its surroundings.

actions of the construction timetable that match with each other

Modelling of surroundings However,

If you have 2D drawings in AutoCAD, you may construct 3D components by importing those drawings into Revit Architecture. In order to integrate them with the database, the 3D components that were developed in Revit Architecture were exported to ArcGIS in the Collada file format.

ArcGIS was used to design the environment around the case study buildings by putting 3D models of all existing infrastructure, including the road network, existing buildings, electric lines, and water supply lines, on a 3D surface model. The case study buildings were also included in this process. It offers a comprehensive view of the site while taking into account the site restrictions imposed by the case study building. Figure 7 depicts a perspective picture of the building that was the subject of the case study, together with its surroundings. It was observed that the development of virtual environments was useful in the preparation of a solid site accessibility plan and earth-work design.

4D modelling

CPM was used to create a timetable for one repetitive unit in addition to four non-repetitive units (foundation, floor number 1, floor number 2, and roof) with the tool that was developed for this particular research. LOB was used in order to arrange 10 identical units for the building that houses the case study. The combined CPM and LOB-based construction schedule has been prepared, thanks to the newly designed tool, and it is now complete. ArcGIS was used to create a 4D model of the execution sequence of the case study building, together with its surroundings, by combining an integrated CPM and LOB-based construction schedule with the building's 3D components. This resulted in the creation of a 4D model. The 4D execution that was created. sequence together with its surrounds is employed here in order to test the accuracy of the generated repeated construction schedule, which can be seen in Figure 8.

Corrections in developed schedule

The construction schedule for the case study building was first planned by the planner without taking into account the real site characteristics or terrain. The construction site is located in a hilly location at a relatively low height, therefore topography does play a significant influence here. As a consequence of this, several unanticipated difficulties were discovered when the first construction timetable was being implemented. These issues are detailed in more detail below:

Case 1

The structure that houses the case study is divided into two distinct sections: the hostel block and the mess block. The building of the mess block was planned to take place as a distinct section of the project and was intended to take place on the front side of the hostel block. Figure 9 displays the earliest version of the mess block's schedule that was established. As can be seen in Figure 10, the originally produced schedule was put through its paces by using the developed 4D execution sequence together with its surroundings (a). When the execution sequence was reviewed virtually with its surroundings, it was discovered that the mess block position was at a relatively low elevation in comparison to the hostel building. This was discovered after the execution sequence was examined. Earthwork of a significant amount was required before the planned architectural design and construction schedule could be accepted. Earth filling at a low elevation area would have needed a significant amount of earthwork and compaction in order to bring it to the necessary height for the construction of a mess block, both of which were very uneconomical. In addition to this, soil filling would

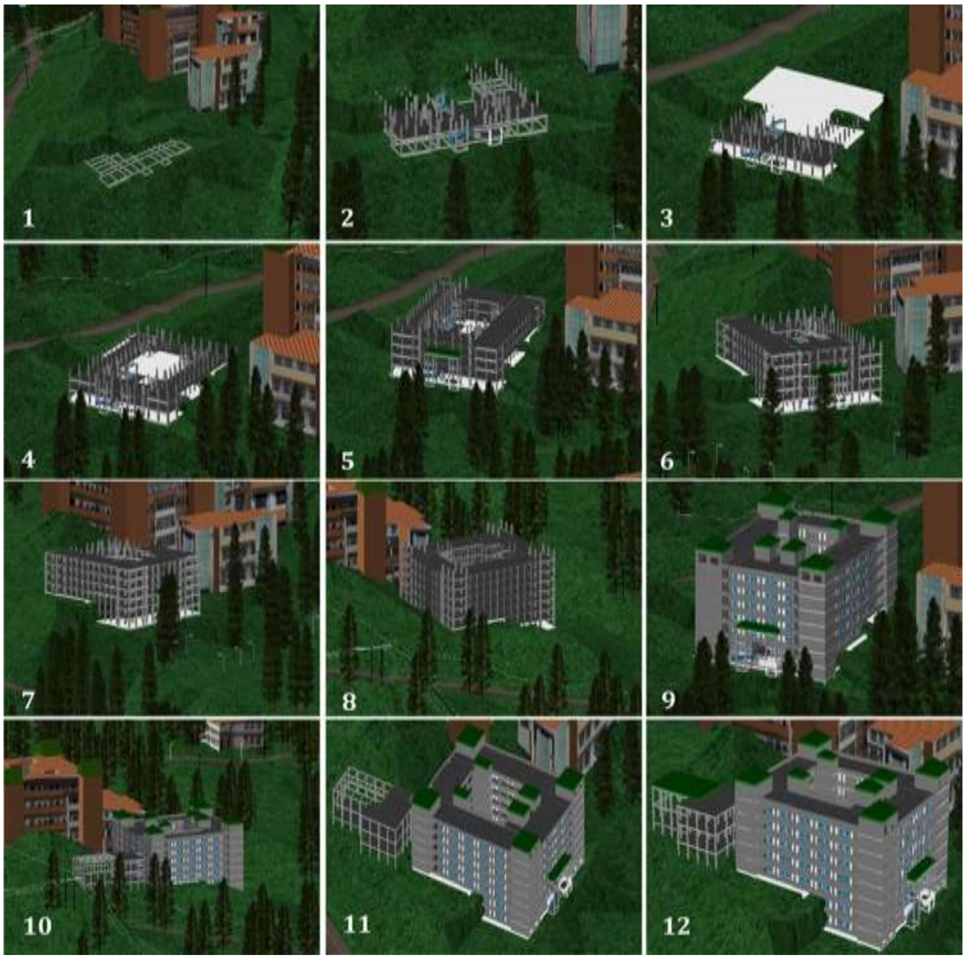


Figure 8. 4D model of the execution sequence along with immediate surroundings of the case study building to facilitate construction planning.

Activity	Duration (Weeks)	EST	EFT	Start Date	End Date
Earthwork (cutting/filling)	14	0	14	11/01/17	19/04/17
P.C.C.	6	14	20	19/04/17	31/05/17
Foundation Reinforcement	8	16	24	03/05/17	28/06/17
Foundation framework	6	18	24	17/05/17	28/06/17
Foundation R.C.C	8	22	30	14/06/17	09/08/17
Backfilling	4	27	31	19/07/17	16/08/17
Plinth beams	4	31	35	16/08/17	13/09/17
Column up to level1	5	35	40	13/09/17	18/10/17
Beams and Slab of level1	7	40	47	18/10/17	06/12/17
Column up to level 2	5	45	50	22/11/17	27/12/17
Beams and Slab of level 2	7	50	57	27/12/17	14/02/18

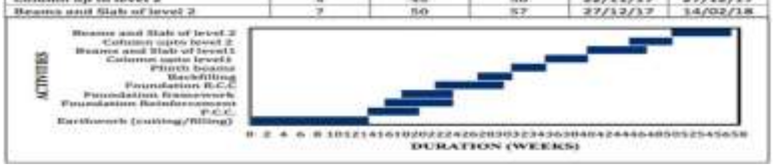
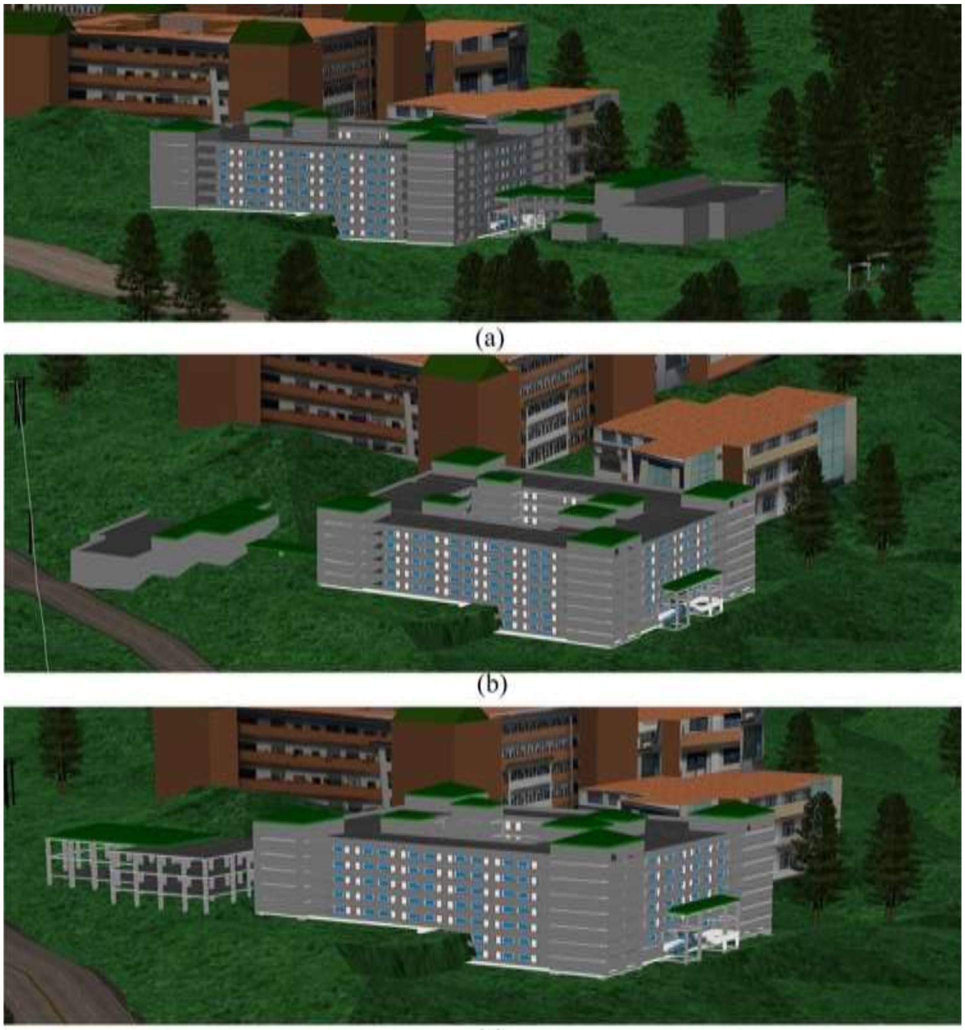


Figure 9. Initially developed schedule of the mess block.



(a) (b) (c)

Figure 10. Use of 4D model for corrections in the integrated schedule: (a) initially planned mess block in front side of hostel block; (b) modified the placement of the mess block to be on the rear of the hostel building; (c) the mess block after the architectural design was revised.

have resulted in a modification to the natural terrain and have blocked the natural drainage of rainfall. The water obstruction on the upstream side would have impacted the drainage pattern of the building site; as a result, some alternate route to the drainage network would have needed to be established. After presenting the execution sequence to the executing agency, they came to the conclusion that the site of the mess block would not be affordable since it would need a significant amount of earthwork (cutting and filling). As a result, the authorities of the institution and the executing agency were unable to accept the timetable that was first prepared. Because the planner at first was unable to correctly read the terrain from the site contour map and was also unable to correctly identify the mess block, the timetable that they developed could not be implemented. Understanding the topography and how it affects the execution of construction work has been aided by the creation of a 4D model that includes its surroundings as well as the topography itself.

Case 2

Any construction in a hilly area without giving significance to its surroundings is a big challenge. Hence, after visualizing the execution sequence withits surroundings and verifying the facts at site, as dis- cussed in the Case-1, it was decided to change the location of mess block toward the backside of hostel block as shown in Figure 10(b). Other two sides (left and right) are not suitable for locating the mess block. The right side is occupied by already existing another hostel building and left side has area less than the required area for mess block construction. Hence, the backside was decided as the best area for the locationof mess block. The mess block was placed on the backside and schedule was revised and linked with the related 3D components. When the 4D execution sequence was revised, it was found that mess block appear very close to the road passing through that

Activities	Duration (Weeks)	EST	EFT	Start Date	End Date
Earthwork (cutting/filling)	1	0	1	11/01/17	18/01/17
P.C.C.	4	1	5	18/01/17	15/02/17
Foundation Reinforcement	2	4	6	08/02/17	22/02/17
Foundation framework	2	6	8	22/02/17	08/03/17
Foundation R.C.C	3	8	11	08/03/17	29/03/17
Backfilling	1	10	11	22/03/17	29/03/17
Plinth beams	3	11	14	29/03/17	19/04/17
Column up to level1	4	14	18	19/04/17	17/05/17
Beams and Slab of level 1	5	18	23	17/05/17	21/06/17
Column up to level 2	4	23	27	21/06/17	19/07/17
Beams and Slab of level 2	5	27	32	19/07/17	23/08/17
Column up to level 3	4	32	36	23/08/17	20/09/17
Beams and Slab of level 3	5	36	41	20/09/17	25/10/17

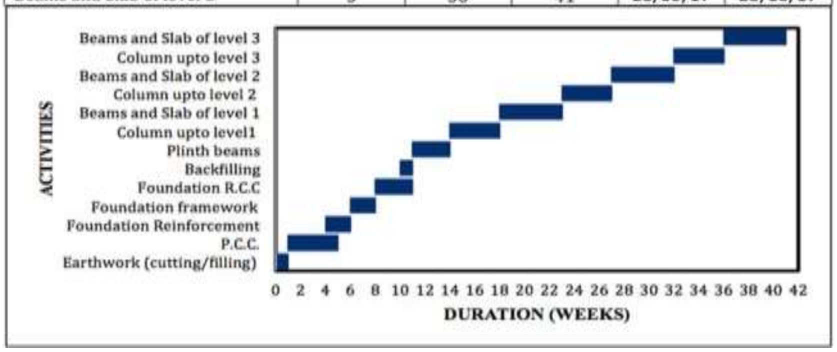


Figure 11. Corrected schedule of the mess block.

location. Even a little modification in the site of the mess building would have required significant cutting of the slope and further retaining work, rendering the location once again uneconomical. In conclusion, this option was not approved by either party, the executing agency, or the institution authorities. Neither of these groups preferred the other.

Case 3

Both sides came to the conclusion that the architectural design for the mess block needed to be altered after visualizing the 4D execution sequence and checking the facts at the site. Following a series of in-depth discussions, it was ultimately agreed upon to lessen the plinth area of the mess block so that it could be accommodated in the space that was available on the rear of the main hostel building. The number of floors in the mess block was raised so that they could meet the floor space requirement. As a result, the execution schedule was altered once again, and connections were made with 3D components, in order to build a new 4D execution sequence, as illustrated in Figure 10. (c). Both parties were consulted on the new 4D execution sequence before a decision was made to go forward with its implementation. After visualizing the execution sequence in conjunction with its surroundings and checking the facts at the location, the timetable was updated, and the result can be seen in Figure 11. The beginning of work on the mess block was to begin on the same day as the beginning of construction on the first timetable, which is seen in Figure 9. It was necessary to lower the size of the plinth area of the mess block in order to fit it into the space that was available on the rear. This resulted in a significant reduction in the amount of earthwork, plain cement concreting (PCC), and cement concreting that needed to be done for the foundation. This resulted in a shorter amount of time needed for the earthwork required, PCC, and cement concrete work in the revised timeline. As a result, the beginning and ending hours of all of the activities have been altered. As a result, the completion of the mess block was planned at a time that was far early than the initial timeline. In the end, all sides agreed that the altered execution schedule would be acceptable since it was more cost-effective, would save time, and would be appropriate for the specific site.

In addition, the produced 4D model of the execution sequence was used to check for missed activities and logical errors in the integrated schedule of the case study construction. As a result, the developed schedule was adjusted to reflect these changes. However, due to the limitations imposed by the length of the article and the abundance of previously published material on the subject, this topic will not be treated further here. The primary objective of this publication is to investigate the impact that the environment has on both the integrated CPM schedule and the LOB-based schedule.

Benefits of the developed tool

The constructed tool for repeated construction projects plans the repeating units by LOB as well as the non-repetitive units by using CPM inside a single GIS platform. Ammar (2013) and Ali and Elazouni (2009) also integrated CPM and LOB methods; consequently, the current study is conducted to provide a visualization platform with a more realistic schedule in nature and to assist practitioners and planners in the scheduling of their repetitive construction projects. This will be accomplished by integrating CPM and LOB methods. The application takes the best features from both scheduling approaches and blends them. Within a single GIS environment, it takes into account logical dependencies by means of CPM and maintains resource continuity with the assistance of LOB. In addition to this, the tool is able to adeptly deal with changes to the integrated schedule of a construction project that involves repeated tasks. A planner may also use it to change and update the generated schedule at any step of the project's execution with ease thanks to its assistance. Python, which is a free and open-source programming language, was used to write the in-house scripts that were used to develop the tool. It makes it easier to convert the output file into different formats in order to solve issues with interoperability. Further, the widely used BIM tool Rivet Architecture has been used to the development of 3D components; however, 2D AutoCAD designs may also be utilized to generate 3D components in Rivet Architecture in correspondence to activities in the integrated schedule.

Scheduling tool was developed in GIS environment to facilitate visualization of 4D execution sequence in conjunction with its surroundings. This is a major shortcoming in most of the commercially available scheduling tools (Mahdi 2004; Hyari and Lucko 2007; Fan et al. 2012; Agrama 2014; Ezeldin and Alhady 2014; Lucko et al. 2014; Lee 2016; Huang et al. 2016; Baqerin et al. 2016). Scheduling tool was developed The difference between developing an integrated construction schedule in isolation and with consideration to its surroundings is significant. When planning is done in a vacuum, it is possible that significant gaps will be left for its implementation; however, when planning takes into account its surroundings, it is much simpler to check for problems that may arise during the process of actually putting the plan into action at a specific location.

Contribution to body of knowledge

The construction timetable may be impacted by the environment that surrounds the work site. In this particular piece of research, the surrounding environment has been digitally modeled using GIS in order to investigate the effect that it has on the established repetitious schedule. The research makes a significant contribution to the creation of a tool for repeated scheduling by combining the advantages offered by CPM and LOB. In a repeating construction project, the LOB is responsible for maintaining resource continuity, whereas the CPM is responsible for managing logical reliance. In order to determine whether or not the generated schedule can be carried out on the given site, a 4D execution sequence together with its surroundings has been built. This was accomplished by integrating the developed schedule with a 3D model of the building. The following is a rundown of the specific contributions made to the existing body of knowledge:

Combined and interactive technique for repeated building is what the current analysis suggests as a possible approach.

scheduling with the development of an integrated CPM and LOB-based scheduling tool inside a GIS context,

a four-dimensional execution process in addition to its environs

has been produced by the integration of CPM and LOB-based schedules with a virtual 3D building model in a GIS environment for the purpose of verifying execution of the generated schedule.

The computer-generated simulation of the environment, including

The use of a 3D execution sequence is beneficial because it helps to keep the site's geographical limits and the impacts of preexisting facilities and utilities in mind when the schedule is being established.

The newly created instrument has been included into the

After seeing the repetitious scheduling of the case study construction as well as the influence of surrounds on the created schedule, the schedule has been adjusted appropriately.

Limitations and recommendations for future studies

Of the current investigation, a timetable for all of the repeated units in an activity that falls under LOB was constructed by maintaining the same production rate throughout. It's possible that the crew will have varying production rates for the various repetitive units that make up an activity. Likewise, the programmed plan could be modified to take into account varying production rates for the various repetitive units that make up an activity. Due to the fact that BIM and GIS were both designed for distinct reasons, it is difficult for one system to comprehend and clarify the data of the other while still maintaining all of its properties. Therefore, more exploration into the data compatibility between BIM and GIS is required in the future in order to successfully use the proposed solution. Another drawback of this study is that GIS only has limited capabilities for 3D modeling; hence, enhancing 3D modeling skills to the level that BIM already has is a worthwhile research field to look into. Despite this, GIS is not a widely used technology in the construction sector; hence, a significant amount of education, training, and research is still necessary to make it more user pleasant.

Conclusions

The purpose of this research is to design an integrated

CPM and LOB-based scheduling tool with the intention of scheduling both non-repetitive and repetitive units of a project that is repetitive. The CPM and LOB approaches have been combined on the GIS platform by means of the newly developed tool. This combination takes into account logical dependencies with the assistance of the CPM and maintains resource continuity with the aid of the LOB. Updates are applied without any problems. the coordinated timetable for a building project that involves repeated steps at any stage.

It is coupled with a 3D model of a project to build a 4D execution sequence in GIS. This is done so that the produced schedule may be verified as having been implemented. BIM is used to construct three-dimensional components that are associated with activities in an integrated schedule. The surrounding environment of the project is modeled with the help of GIS. The virtual modeling of the environment aids in understanding the effect that the environment has on the schedule that has been prepared. In order to ensure that the integrated schedule has been correctly implemented, the 4D execution sequence has been seen in GIS in conjunction with its environs. Integrated scheduling provides for the verification of a project's spatial feasibility, executability, constructability, as well as the identification of missing activities, logical mistakes, and time-space conflicts. This is made possible by keeping in mind the surrounds of the project.

GIS now makes it possible for planners to create integrated

schedule, combining 3D components with integrated schedule, and modeling surroundings of a construction project in a single platform to produce 4D execution sequence together with its surrounds. This may be accomplished by developing 4D execution sequence. When it comes to scheduling repetitious tasks, the tool that was built is a superior option to scheduling applications that are available for purchase on the market.

Disclosure statement

The writers did not mention having any possible conflicts of interest in their paper.

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