Building Schedule Risks Simulation by Using BIM with Monte Carlo Technique

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Abstract. Risk management in construction projects has great importance through its impact on the basic objectives of the construction projects, as controlling the risks of the construction projects helps reduce cost overruns and time overruns and improve the quality of the construction projects. This paper aims to highlight the role of BIM in risk management in construction projects by generating a predictive risk model using Monte Carlo simulation to analyze a number of risks and generating a 3D model and 4D model to show the effect of risks. The predictive risk model can help project managers control the risks that affect the construction projects and enhance communication between all stakeholders for the project. The methodology was applied to two risk scenarios, the optimistic scenario for risks, and the pessimistic scenario for risks in one of the construction projects in Iraqi through the use of four commercial programs working together. The study concluded that the building information modeling technique has great importance in reducing the risks affecting the construction project by showing the effect of these risks during the project's construction phases and controlling them.

Keywords: Risk identification; building information modeling; construction project risks; Monte-Carlo simulation; 4D simulation; activities project scheduling.

1. Introduction
A multistep and interdisciplinary process characterizes construction projects. The implementation of the construction project requires the participation of a large team of specialists in different fields such as architects, investors, contractors, and construction supervisors. Each party in the construction process has their own objective, and they rely on their own strategy to achieve them. Communication between project teams at each stage in the project life cycle is necessary for achieving the proper cooperation between all project teams in each project [1]. Also, Insufficient data and uncertainties in modeling have a significant role in many engineering and management problems. Therefore, the application of some techniques is essential for attaining the proper solutions under accurate consideration [2]. Most of the construction enterprises Headed towards using BIM programs for their projects [3]. The BIM provides an easy-to-use environment for project design, modification of the 3D model, as well as storage of data for the 3D model [4].

BIM can be considered an effective tool in creating a virtual environment for the project similar to the actual environment for the project job site that can be used for identity and solve project risks in the early project stages [5]. Another feature of BIM technology is the ability to share information between different project parties during the various stages of the project [6]. Based on these features and characteristics of BIM technology, BIM can be used as an effective risk management technology [7]. Which is an important process when planning and constructing the construction project [8]. BIM helps
deal with the high complexity of construction projects that affect the basic objectives of construction projects [9]. It also facilitates communication between all project parties to successfully manage the construction project's risk [10]. The project team is exposed to great stress to complete the project within the specified budget and schedule at the construction stage. There are many risks and uncertainties during this period. To identify project risks and improve them at an early stage and improve construction sequence, [11] conducted a 4D simulation and clash detection for the construction of a steel bridge. [12] used the 4D model to manage the quality of the project depend on construction codes and established a model for quality control. [13] Develop an application that integrates BIM with Earned Value (EV) for schedule and cost control and finds project status on specific dates in the report for infrastructure bridges.

From the previous studies, it has been found that efforts still focus on used BIM in the design and construction stage. BIM can also be used in other processes and phases such as maintenance management [14], demolition [15], and facility management [16]. In addition, the environment of collaboration and communication for BIM may facilitate risk identification in early-stage and mitigation [17]; [18]. Through previous studies, it was noted that there is a weakness in the application of BIM technology in risk management in construction projects, so this study tries to shed light on some of the characteristics of BIM technology for risk management by using 4D simulation to show the effect of risks on the construction project.

The construction projects in Iraq face great risks due to the lack of understanding of the political, economic, cultural and legal conditions of the construction project in a large way, as well as the lack of evaluation of the performance of the construction project in the design stage, which affects the main objectives of the project (cost, time, quality). In this study, the researcher tries to achieve the following goals:

1) Determine the most important risk factors that affect the project implementation period and time overrun in Iraq’s construction project.
2) Identify and innovate the most appropriate and effective applications and methods for managing construction project risks by developing a hybrid technology that uses risk management techniques along with BIM to assess and address risks in construction projects.
3) Building a predictive model for risks.
4) Highlighting the quantitative and visual evaluation of risks through a visual simulation of the impact of risks gives a clear visualization of the impact of these risks on the construction project.
5) Determine the planned project duration from the information gathered and compare it with the actual project completion duration to identify the effect of the risk factors on project time.
6) Using BIM technology to assess and demonstrate the impact of the diagnosed risks on the performance of construction projects.

2. Research methodology
The Guide to Project Management Knowledge Area represented the project life cycle (initiation, planning, execution, and closeout phases). The BIM technique is commonly applied in the early stages of the design stage to increase the efficiency of the construction project and achieve its primary goals. Initial drafts are designed in two-dimensional form, after which they are developed into three-dimensional models by the BIM, which helps in calculating quantities for the construction project accurately, controlling time and cost, and managing the construction project during the implementation phase. Figure 1. represents the methodology used to manage risks using BIM. The research methodology can be summarized as follows:

- Conduct a literature review for the previous studies within the scope of the research, which includes (papers, thesis, websites, books).
- Identify a case study and collect information on construction projects (2D drawing, data, project duration, priced schedules quantities).
- Generating a 3D model for the building by using Autodesk’s Revit 2020.
- Collect information about the type of risk factors that faces construction projects in Iraq from previous studies and personal interviews for many project managers, consultants, supervisors, and contractors and design a questionnaire to identify the probability and
impact of each risk factor for defining the most construction project risks in Iraq and analyze the data by using Social Sciences (SPSS) V25 and Microsoft Excel 2010 software.

- Using probability and impact matrix technique for conducting the qualitative risk analysis and selecting the risks with a very high level of influence is illustrated in Table 1.

### Table 1. The most critical risks in the construction project.

| No. | Risk factor                                                                 |
|-----|-----------------------------------------------------------------------------|
| 1   | Error in estimating the quantity of material                                |
| 2   | The inability of the owner to finance the project                          |
| 3   | Change in design                                                            |
| 4   | Design difference between structural and architectural                     |
| 5   | Effect of change order                                                      |
| 6   | Lack of experience of the contractor in the implementation of construction works |
| 7   | Inaccurate scheduling                                                       |
| 8   | The difference between bill of quantity and plan                            |
| 9   | Unclear of the owner's requirements                                         |
| 10  | The occurrence of risks excluded by both parties to the contract           |

- Using MS Project 2010 software by Microsoft project for scheduling the project details (start, finish, duration), after that XML format is imported to risky project professional 7.1 by INTAVER Institute for conducting the quantitative analysis of the risks obtained from a questionnaire. Two scenarios are adopted in this study, the optimistic and the pessimistic scenarios. The optimistic scenario assumes that risks have a low level of occurrence and effect on a project, while the pessimistic scenario assumes that risks have a high level of occurrence and effect on a project.

- scheduling the probabilistic project duration obtained from the Monte Carlo simulation by using MS project software.

- Finally conducting the integration of the output of the previous stages by using Navisworks manage 2020 by Autodesk that is compatible with both MS project and Revit and making 4D simulation for different scenarios and discuss the effect of risk on project duration through the simulation result and conclusions and recommendations that reached by the researcher. Figure 1 represents the methodology adopted in current research.

### 3. Experimental works

3.1. Case study: internal department building no. (1) at the University of Diyala.

The case study selected is the Building of internal departments at the University of Diyala. It's one of the Diyala university projects. It consists of three-floor with an area (6000 m²). The University of Diyala transferred the project to a local company on 6/11/2013 with a period of (365) days at a total cost of (3,418,298,095). The project was stopped on (27/3/2014) and work on the project was resumed on (21/11/2019) to complete the remaining works, and the project has not been completed yet. The project details are shown below:

- Project name: Building of internal departments
- Type of contract: unit price contract
- Project duration: 365days
- Project planned start date: 6/11/2013
- Project planned finish date: 5/10/2014.
Figure 1. Research methodology.

3.2. Generate 3D model for the selected case study

The author used Revit software from Autodesk to generate 3D model for the building, as shown in Figure 2. The main reason for selecting this software is that it allows for the creation of a 3D model for the building in a simple way and easy compared to other programs and its high-quality graphics and can produce a better image significantly, and It is also available free as a student version for two years.

Figure 2. The 3D BIM model of the case study.

3.3. Scheduling the project activity

After completing the project information collection, it is important to schedule the project activities using MS project software; planned start time, planned finish time, and duration are assigned to each activity and considering relations between activities. Figure 3. illustrates the Gantt chart view. The Generated Gantt chart was imported to the risky project software that allows the Monte-Carlo simulation for the project period and gives the project summary.
Figure 3. Planned construction scheduling for the case study.

4. Results and Discussions

The results of this research were conducted and discussed according to the following stages:

4.1. Monte Carlo Simulation

The result of the Monte Carlo simulation is the project summary that includes information about the project with and without risks, start time, finish time, duration. The result shows a difference between planned project duration and expected duration due to the risks. The results for the optimistic scenario show the project duration with no risks is (316) days, and with risks, the base duration is (345.5) as shown in Figure 4.

The project summary provides a frequency chart for the project that represents the completion time and duration of the project. In this chart, the project completion and duration confidence level can be illustrated as a percentage. Figure 5 illustrates the frequency chart for the project finish time. The result of statics was illustrated as ranges. This range is between (2/10/14 to 6/03/2015) with a mean of 5/11/14 was most runs set. The deterministic date for the project is 5/10/14, and from this chart, the probability of completing the project is 0%. The probability of completing the project on 31/10/2014 is 50%. At a 90% probability, the project can be completed on 10/12/2014. The frequency chart enables the project managers to investigate the probability rate for completing the project at any time.

The second frequency chart illustrates the project duration as shown in Figure 6. The result of statics was illustrated as ranges. This range is between (312.7 to 459) days, and the mean was (345) days was most runs were set. The deterministic project date was (316 days), and from this chart, the probability of completing the project is 0%. The probability of completing the project in (339.9 days) is 50%. At a 90% probability, the project can be completed in (378 days).

Risky project allows presenting the tracking chart for the project summary depending on the deterministic and probabilistic duration. The calculation aims to reassess the project duration, start, and finish dates based on the actual progress. The tracking chart helps the project managers to compare the
original estimates with the forecasted schedule. Figure 7 shows the tracking chart for the optimistic scenario.

| No Risks       | Cur. Schedule | Project Start Time | Project Duration | Project Finish Time |
|----------------|---------------|--------------------|------------------|---------------------|
| Low            | 11/06/13 08:00 | 315.88 days        | 10/05/14 14:00   |
| Base           | 11/06/13 08:00 | 320.27 days        | 10/10/14 10:12   |
| High           | 11/06/13 08:00 | 345.5 days         | 11/06/14 17:00   |
| With Risks     | 11/06/13 08:00 | 378.2 days         | 12/10/14 13:34   |

**Figure 4.** Project summary for the optimistic scenario.

**Figure 5.** Frequency chart for the project finish time for the optimistic scenario.

**Figure 6.** Frequency chart for the project duration for optimistic scenario.
The results for the pessimistic scenario show the project duration with no risks is 316 days, and with risks, the base duration is 1977 as shown in Figure 8. The result of the frequency chart provided by the project summary for a pessimistic scenario for the project finish time can be illustrated in Figure 9. The range of static results is between (20/4/2015 to 31/8/2020) with a mean of 19/1/2019. The deterministic date for the project is 5/10/14, and from this chart, the probability of completing the project at this time is 0%. The probability of completing the project on 11/3/2019 is 50%. At a 90% probability, the project can be completed on 10/8/2019. From the result of the project summary, there was a high difference between the planned and probabilistic project time for completing the project.

The frequency chart of the project duration for the pessimistic scenario can be shown in Figure 10. From this chart, the range of statics results is between (501.9 to 2356.99) days, and the mean was (1799.11) days was most runs set. The deterministic date for the project was (316 days), and from this chart, the probability of completing the project is 0%. The probability of completing the project on (1847.36 days) is 50%. At a 90% probability, the project can be completed in (2066 days). The tracking chart for the pessimistic scenario can be shown in Figure 11.
**Figure 9.** Frequency chart for the project finish time for pessimistic scenario.

**Figure 10.** Frequency chart for the project duration for pessimistic scenario.

**Figure 11.** Tracking chart for the pessimistic scenario.

### 4.2. Navisworks simulation videos

The quantitative risk analysis results can be shown in a visual format to show the effect of risks on each activity in the project. The process can be done by using the Navisworks manage 2020 that provided by the BIM technique that allows 4D simulation for the building. This stage is representing the integration between risk management and BIM. The probabilistic project duration for each scenario obtained from
The Monte Carlo simulation was scheduled by using MS project 2010 software. These schedules were imported to Navisworks software and imported the 3D model and linked each activity in the construction schedule with its element in the 3D model for generating the 4D model. The simulation videos were conducted for a no-risk scenario, optimistic scenario, and pessimistic scenario. The virtual view resulting from 4D simulation helps adjust the project schedule according to any changes in the design of the project, which is difficult to achieve these adjusts by using the traditional planning methods.

The presence of color code property in 4D simulation allows an effective visualization for the project activities progress where the Green transparent color represents activity in start appearance, which facilitates to understand the construction project progress with the date. The simulation video of the project model helps in understanding a complete visualization of the progress of the project activities by comparing the planned project start date with the actual and the planned project end date with the actual date, which facilitates understanding the impact of risk factors on project implementation time, the result of simulation videos can be seen in Figures 12, 13, 14, 15, and 16 which illustrates a screenshot of simulation videos for different scenario.

**Figure 12.** Simulation video screenshot at 330 days for no risk scenario.

**Figure 13.** Simulation video screenshot with completion date for no risk scenario.

**Figure 14.** Simulation video screenshot at 330 days for optimistic scenario.
5. Conclusion
The risk management process is one of the important stages in any construction project because of the uncertainty surrounding the construction projects, as identifying and assessing risks is of great importance in reducing cost and time overruns as well as improving the quality and safety of the construction project. Where modern technologies (BIM) help accelerate the risk management process and show the risks in a clear manner that the stakeholders can easily understand. The virtual view for the project schedule obtained from the 4D simulation can help monitor the project and adjust the schedule according to the design change because the activities in the simulated construction schedule are linked to the building elements of a 3D building model.
The proposed methodology used in this research can be applied to all types of projects and at any stage of the project, especially the design and implementation stages. Several scenarios can be proposed, examined, and evaluated for the same constructive model. The results of the Monte Carlo simulation clarify that there is a difference between planned project duration and probabilistic project duration due to the risks that affect the project. The 4D simulation of the probabilistic project duration can help to understand the effect of risks in construction.

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