 

# Risk Analysis of Healthcare Projects Using Simulations

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Risks to owners, designers, engineers, and contractors are prevalent in healthcare projects. Therefore, it is essential for an organization to have qualified risk managers to assess, develop, implement, and monitor risk management plans with the goal of minimizing exposure. The purpose of this research is to build a risk analysis framework using simulations to fulfill the requirements in the interest of professionalism and quality performance. This research focuses on the priorities to the project team for a healthcare organization, such as estimating, scheduling, safety and most importantly, quality of work. Based on the information from a real-world project and using @Risk software with Monte Carlo simulations for analyzing the risks associated with project budget and schedule, the results show a complete set of outcomes for possible situations of the project. The simulation results also provide insight to project quality and safety issues. The suggested risk management plan is pertaining to the risk analysis results with the probabilities calculated from statistical evaluations. This risk analysis framework and the simulation results provide competitive pricing and a comprehensive risk-management program for project management. This paper helps the project stakeholders, employees, and construction workers to understand the multiple variations of risks, in addition to making all aspects of the project a success.

**Key Words**: Risk management plan, project simulation, time cost tradeoff, risk analysis and presentation

## Introduction

Construction companies are committed to fulfill all requirements in the interest of professionalism and quality performance. In healthcare projects, companies should make all efforts in assuring project quality under mutually agreed time and budget (Talib and Rahman 2015). In addition to competitive pricing and comprehensive safety programs for workers and employees, project teams need to make all aspects of the project a success (Kerzner and Kerzner 2017). More importantly, project teams should satisfy customers' expectations at the highest standard to create successful experiences (Kerzner and Kerzner 2017; Lucko 2013; Robichaud and Anantatmula 2010).

There are many risks associated with a construction project. They must be identified as early as possible to assess, develop, implement, and monitor risk management plans with the goal of minimizing exposure (Haimes 2015; Hyun et al. 2015). Due to the complexity of healthcare construction projects, the lifecycles of these projects have abundant uncertainties (Batalden et al. 2015; Talib and Rahman 2015). The frequent occurrence of risks in the healthcare projects means that the buildings must be specifically evaluated and monitored to avoid or mitigate the risks associated with cost overruns and project delays. For example, risks in the planning, construction, or commissioning can have profound consequences to the cost and schedule of the project and must be accounted for in prompt manners to ensure the project remains on schedule and budget (Lucko 2013; Stark 2015). For construction projects, the project managers and project teams need to develop risk registers to keep track of risks during the entire life cycles of the projects (Haimes 2015; Haimes et al. 1995). However, the manual creation and updates of risk registers cannot preventively identify the probabilities of risk occurrences and place them in an appropriate category (Akgün et al. 2015; Haimes 2015; Heredia et al. 2017; Hyun et al. 2015).

This paper focuses on the priorities to the project team for a healthcare organization, such as estimating, scheduling, safety and most importantly, quality of work. The research includes a literature review on the management challenges of healthcare projects, risk analysis and simulation, and project control. This paper suggests a customizable and exportable graphing and reporting option that helps to communicate risk to all the stakeholders. Based on the information from a real-world project and using @Risk software with Monte Carlo simulations for analyzing the risks associated with project budget and schedule, the results show a complete set of outcomes for possible situations of the project.

## Literature Review

Healthcare projects are distinct from other commercial projects in that they are complicated in nature and have tremendous unpredictable (Batalden et al. 2015; Talib and Rahman 2015). Project managers face the challenges of identifying risks and coordinating resources in healthcare projects, including risk analysis and simulation, as well as project control (Akgün et al. 2015; Haimes 2015; Ruan et al. 2017). For risk identification purpose, it is common to break down risks to their sources of external and internal to the project (Haimes et al. 1995). External risks are associated with nature, political, legal and economic risks. Internal risks involve managers, contracts, technical and human factors. A risk register associated with a construction project highlights how basic risks can be identified (Dunović et al. 2013). Within the scope of this paper, there are three key risks identified as the main contributors to this new construction project of the healthcare facility. They are tight project schedule, design variations, and construction program planning. The top risks are chosen because their occurrences can significantly influence time and cost for the clients, designers, and contractors (Akgün et al. 2015; Haimes 2015; Ruan et al. 2017).

To access these risks, this paper uses the survey data from a research paper (Zou et al. 2007) and couples it with a risk index from the International Journal of Project Management (Taroun 2014). To obtain the significant scores of risks, a survey was completed where respondents would assess risks based on probability level of that risk (*A*) and the impact of that risk if it were to occur (*B*). Therefore, the risk significance is a function of *A* and *B* (Zou et al. 2007). Shen and Wu (2001) surveyed 54 individuals to obtain significance scores to compare the risks. The respondents' results were simply multiplied and averaged together to calculate the significance ($S = f(AB)$). As shown in Eq. 1, n is the number of respondents to survey for the question x. Previous literature shows that the risk of tight project schedule has a risk rating of 0.67, the risk of design variations has a rating of 0.49, and the risk of construction program planning has a score of 0.42 (Shen et al. 2001; Zou et al. 2007).

$$Risk\ Significance = \frac{\sum_x^n s}{n} \quad (1)$$

The schedule constraints represent the highest risk significance (Shen et al. 2001). Ensuring that the project schedule is well planned out and appropriate for the scope of work is one of the most important aspects of the project planning and has large implications to cost and schedule. There must be enough resources for the project to mitigate this risk and maintain the project to run smoothly from beginning to closeout. The risk of design variations is the result of revisions to the initial design due to client choices, engineering constraints, or communication mishaps. Any change to the design can have lasting effects on the project in the terms of cost and schedule. To help mitigate this risk, project managers should establish proper communication lines between designers, engineers, and the client to ensure the best possible outcome is achieved and the appropriate amount of time is scheduled for the design to be realized and finalized. The risk related to construction planning has the next high rating. According to Shen and Wu (2007), time-related risks such as excessive administrative procedures and client variations were higher in significance scores (.47 and .48 respectively). It is possible to incorporate these factors into construction planning risks and use them as possible delays in construction planning. This risk mostly is the product of new designs and unforeseen criteria by the client or designer. This risk can be reduced by allowing proper buffer time for planning and appropriate precise scheduling.

Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and their probabilities for any choice of action. It shows the extreme possibilities (the outcomes of going for broke and for the most conservative decision) along with all possible consequences for middle-of-the-road decisions. Using Monte Carlo simulations and @Risk software, researchers can create models and simulations of the possible variations of costs and schedules of construction projects (Akgün et al. 2015; Haimes 2015; Hyun et al. 2015; Taroun 2014). Based on the virtually possible outcomes for any situation that might happen in a construction project, project managers can determine which risks to take on and which ones to avoid. The proposed risk analysis framework provides critical insights in today's uncertain world. Monte Carlo simulation is a computerized mathematical technique that allows project managers to account for risk in quantitative analysis and enhance decision making.

## Research Questions and Method

This research project sought the answers to the questions, "*What are the priorities to the project team for a healthcare organization, such as estimating, scheduling, safety and most importantly, quality of work? Can project managers use simulations for analyzing the risks associated with project budget and schedule? How do project teams create a complete set of possible outcomes for various situations of the project?*" The following paragraphs explain the details to find the answers.

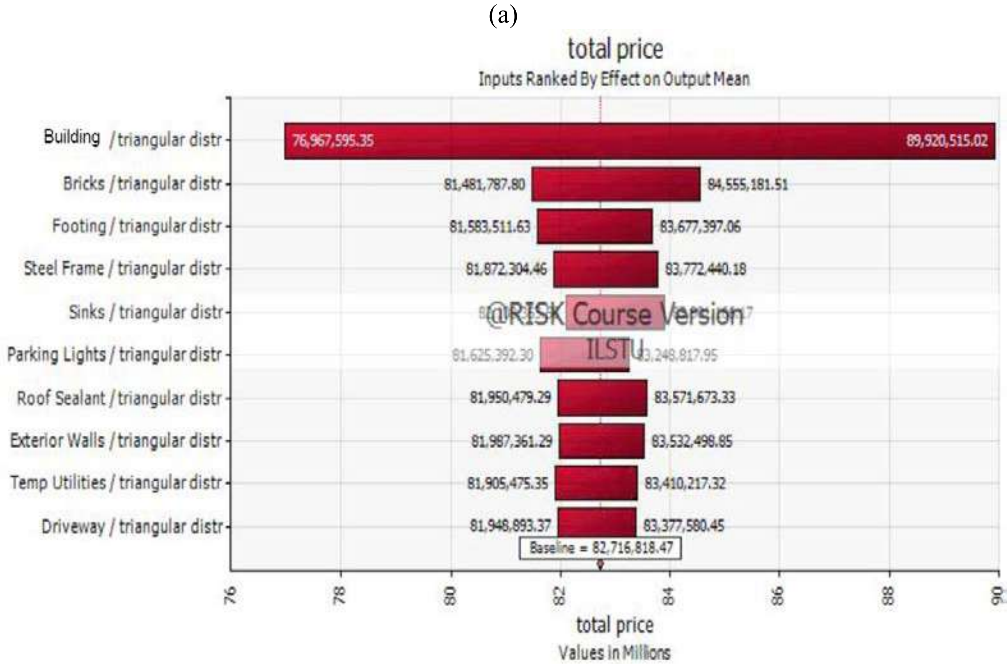
After building the simulation framework and verify it with computer-generated data, this research used the project information and data from an actual hospital project to validate the framework. This is a six-story building with 40,000 square feet of physician offices and conference rooms along with a chronic care center and an emergency center. The doctors and conference space are on the 4th floor so that the hospital can install a new 12-bed intensive care unit and a 12-bed observation unit on the 2nd and 3rd floors respectively. The budget developed for this specific project consists of several critical parts: category, equipment/service, quality, total price, and man days. In addition, there are 21 main categories which were included to the budget: Ambulance Bay, Base, Ceiling, Central Heating, Concrete, Doors, Duct Work, Electrical, Elevator, Fire, Floors, Paint, Roof, Sewer, Staircase, Storm Drain, Temp Utilities, Unit, Walls, Water System, and Windows. All these categories cover the main scope of the project. The budget is subject to change based on cost and quality analyses, as well as continuous improvement through regular reviews and retrospectives. The Monte Carlo simulations are performed for the following categories:

1) Perform risk analysis by building models of possible results for total price, by substituting a range of values (a probability distribution) for "Total Price" which holds inherent uncertainty. The initial data set of this project was relatively small. The data set was entered to the @ Risk software by the authors. The next step was to import the data of previous similar projects to Excel data then into the software. The authors performed stakeholder surveys in the project team and compared the survey results to published records (Shen et al. 2001; Zou et al. 2007). The ultimate adjusted survey results helped the project team to define the Triangular Distribution.
2) Use Triangular Distribution to define the minimum, most likely, and maximum values for "Total Price". The assumptions of the percentages for minimum, maximum and most-likely are from the stakeholder surveys (Shen et al. 2001; Zou et al. 2007). The next step is to run the Monte Carlo simulations with the defined settings. The simulations will generate the outputs.
3) During a Monte Carlo simulation, values are sampled at random from the input probability distributions. Each set of samples is called an iteration, and the resulting outcome from that sample is recorded. These simulations provide comprehensive views of what may happen. Using risk output on the total sampled price, the simulation has 1,000 iterations.
4) Use customizable and exportable graphs and reports to communicate risk to all the stakeholders. Figure 1(a) shows an example of using @Risk software to explain the possible changes of the total price and potential risks. It includes both the range of total price (between $76.76 and $89.71 million) with 90% confidence level and the range (between $75.91 and $90.62 million) with 95% confidence level. Using the tornado graph function of @Risk software, the results of the Monte Carlo simulations can be imported to a tornado chart as shown in Figure 1(b). The tornado chart shows the sensitivity/risk associated with each uncertainty or variable. A decision maker needs to visually compare the budgetary items and identify the ones to focus on.
5) In addition to the risk analysis on budget, the project team uses the same process for the risk analyses on schedule, safety and quality of work. The simulations and analyses are based on the expert knowledge from the project team, literature review, and company database. The project team discusses the simulation findings in scheduled group meetings for information exchange (as shown in Figure 2).
6) The risk analysis process iterates in the preconstruction stage. The group meetings provide new suggestions, questions, and knowledge about the project. The authors perform simulations with the updated information for the project team after every group meeting. The outputs of the simulations are in a risk analysis report with calculations, graphs and charts (e.g. Figure 1).

## Simulations and Results

To clarify the risks and where they are associated within the project lifecycle, Figure 2 shows the diagram of how to schedule risk management in each stage of the project lifecycle for the construction project and which stakeholders that they are associated with. The diagram integrates the needs of risk management planning (RMP) related to stakeholders with the factors of information exchange for risk management factors and activities. This diagram considers the BIM execution plan (McArthur and Sun 2015) that is used for implementing BIM in the construction industry and risk management planning (Burtonshaw-Gunn 2017) for healthcare projects (Haimes 2015). The timeline on the figure indicates the expected meeting dates of the healthcare project in the following case study. The hospital project in this case study used design-build delivery method. The rule of information exchange followed the standards of design-build project management guidelines (Molenaar et al. 2015) and Construction Operations Building Information Exchange (COBIE) (East 2007). This gives the project team insight at the beginning of the project on what risks are identified up front. It helps the team to understand when to pay particular attention to what risks and how to identify them.


(a)




(b)

*Figure 1* Risk analysis on Budget. (a) Statistics distribution; (b) Tornado chart.

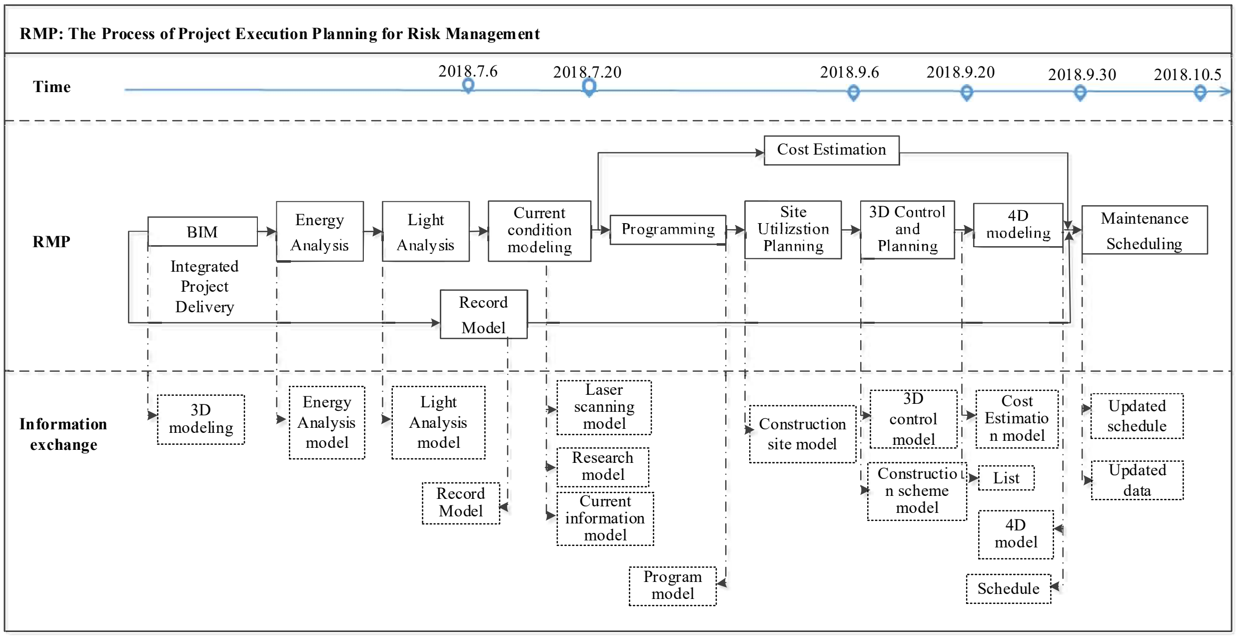
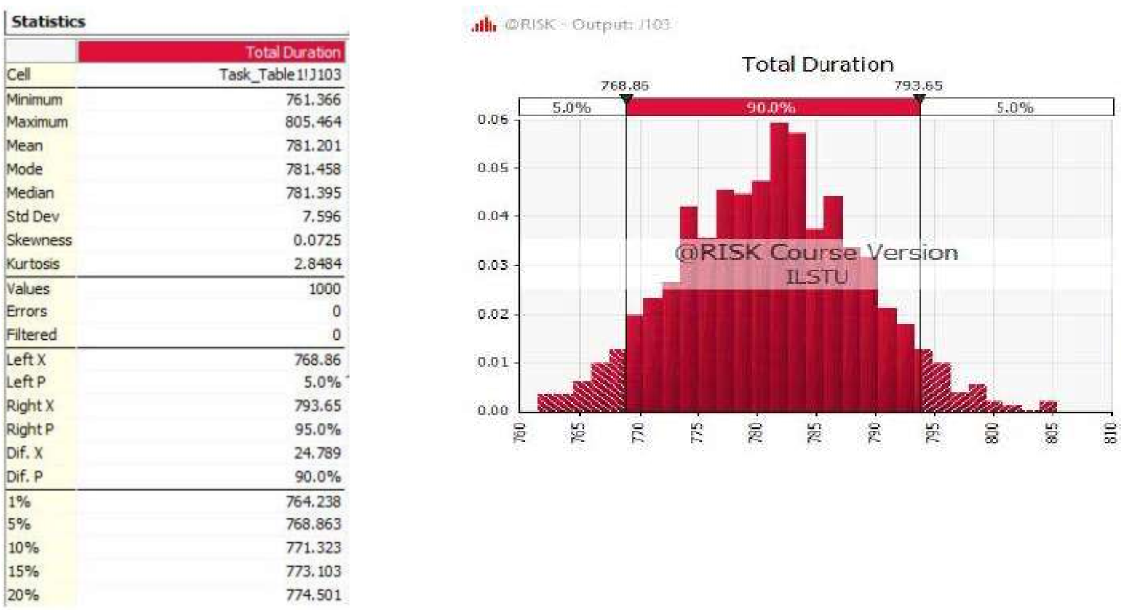



*Figure 2*: Process of Project Execution Planning for Risk Management (Adopted from McArthur and Sun 2015).

The authors ran the Monte Carlo simulation on the schedule's total duration time for 1000 iterations as the base and ran one simulation with the output as the total duration based on triangular distribution. The minimum duration was in 90% probability. The most-likely duration had 100% probability. The maximum duration was in 75% probability. When using @Risk software to perform the schedule analysis, the authors started with 90% confidence level that the project's duration was between 768 and 793 days. The earliest time to finish the project was in 761 days, while the latest time to finish the project was in 805 days with the standard deviation of 7.5 days. This analysis shows that the standard deviation was high and the project was at a higher risk due to 7.5 days of fluctuation in the schedule. If the project is delayed by 7.5 days, it will incur high additional costs for the delay. To improve the overall schedule, further analysis should be taken on the root cause of the delay and focus on those tasks that may cause the delay. Figure 3(a) shows the schedule analysis summary using @Risk software. Figure 3(b) shows 90% confidence interval of the schedule duration.

The healthcare project was scheduled to begin May 6, 2018 and end May 6, 2020. Based on the scope of the project, available resources, and emphasis on risk mitigation, the most effective approach was to utilize waterfall methodology and schedule accordingly. The schedule contained five major sections including the following: Addition of 4th floor, Addition of 5th floor, Addition of 6th floor, Renovation of the Ambulance Bay, and Renovation of the Entrance. Each addition had a Finish-to-Start relationship with the preceding addition and was in respective order according to the project schedule. In the schedule, the final Project Milestone aligns with the final Project Delivery Date, which indicates acceptance of the final product by the client and total completion of this project. There are 121 individual tasks identified to ensure comprehensive planning of work, proper allocation of resources, and adherence to resource constraints. The project schedule provides the details of all dependencies and relationships between the identified tasks. The duration of each task has been estimated based on previous projects completed and with the inputs of leading experts in literature review. The critical path of the project schedule includes 58 tasks and will be monitored continuously. There are slacks built into the schedule to mitigate the risk of schedule overrun. To ensure transparency and stakeholder involvement, Risk Review Meetings have been scheduled every week in the project timeline. These meetings will include progress updates, Earned Value Reports, and images of completed work. Courtesy of built-in slack, emergency meetings will be able to be scheduled if necessary.



| Statistics | Total Duration |
|---|---|
| Cell | Task_Table1!J103 |
| Minimum | 761.366 |
| Maximum | 805.464 |
| Mean | 781.201 |
| Mode | 781.458 |
| Median | 781.395 |
| Std Dev | 7.596 |
| Skewness | 0.0725 |
| Kurtosis | 2.8484 |
| Values | 1000 |
| Errors | 0 |
| Filtered | 0 |
| Left X | 768.86 |
| Left P | 5.0% |
| Right X | 793.65 |
| Right P | 95.0% |
| Dif. X | 24.789 |
| Dif. P | 90.0% |
| 1% | 764.238 |
| 5% | 768.863 |
| 10% | 771.323 |
| 15% | 773.103 |
| 20% | 774.501 |



(a) (b)

*Figure 3*: (a) Schedule analysis summary using @Risk software. (b) 90% confidence interval of the schedule duration

## Discussion

The risk analysis through simulations helped to make sure the healthcare construction project would be on schedule, with controlled cost and of good customer satisfaction. The project constraints included noise level control, structural limit of the building, patient and employee traffic flows, and environmental hazards. In addition, the analysis considered the following guidelines:

1) Insure the health and safety of everyone involved and affected;
2) Maintain clean and hazard free work area;
3) Highlight the milestones dates such as: notice to proceed, budget engineering and construction review, start of construction, design completion, exterior work completion, substantial completion, project commissioning, and close out;
4) Achieve overall satisfaction of design and products

Based on the risk simulations, time-cost tradeoffs, and risk management planning process, the following tasks have noteworthy influences on project success.

1) Ensuring realistic completion dates: It seems simple, but confirming that deadlines are achievable is one of the most important elements of schedule analysis.
2) Highlighting client-driven risks: Appropriate time needs to be built into programs of work for activities that clients own. Frequently, time is underestimated for tasks such as sign offs, approvals and access dates, which all have a detrimental effect to the program.
3) Highlighting project risks: As identified within client-driven risks, it is important to establish the overall project risks. Throughout the project there should be a focus regarding potential project risks to ensure that all known risk can be managed accordingly and the likelihood of these risks having an effect reduced.
4) Managing change: Analyzing the schedule for potential changes, and understanding the likely effect of a change, is hugely beneficial to programs of work. If you consider how much of the value of the program relies on accuracy and efficiency, ensuring effective change management is in place is key to success. Programs with effective change management in place are more likely to meet objectives, stay on schedule and stay on budget.

Below is the list of risks identified in the research of risk analysis for healthcare projects:

1) Health Risks: Sick patients can pass diseases to workers. Workers may get sickened by the contaminants.

2) Technical Risks: Technical risks include incomplete design, inadequate site investigation, and uncertainty of resources. These risks can happen if there are design errors or change is requirement or change in project scope.
3) Environmental Risks: This include seasonal implications, natural disasters. Preparation for possible weather risks can avoid potential delays and losses. When working on a project it's very important to get familiar with that region's weather patterns.
4) Logistical Risks: Logistical risks include availability of transportation facilities and equipment, such as fuel, spare parts etc. Overlooking logistical issues poses a great threat to project delays and losses.
5) Socio-political Risks: Inflation and import restrictions are few risks under this category. Depending upon the project location, there are different set of rules/regulation the project team need to abide by.
6) Management related Risks: uncertain productivity of resources is one risk here. Before starting a project, managers should make sure they have sufficiently skilled staff. Furthermore, they need to define every role and responsibility clearly.

Based on the different categories of risk identified, project teams must create plans to tackle the listed risks. Below is the mitigation plan for each risk category.

1) Health Risks: To mitigate the health risks, the project team should provide a clean and germ-free environment.
2) Technical Risks: To mitigate various technical risks the team can search for alternate resources. To handle material availability risk, the team should ensure proper inventory of materials and site investigation.
3) Logistical Risks: Logistical risks relate to the availabilities of transportation facilities and equipment. To mitigate these risks, the team needs to make sure that there are adequate transport facilities with emergency backup, spare parts, fuel and labor available in advance.
4) Environmental Risks: Mitigation plan includes having a good knowledge of local weather to avoid natural disasters and seasonal implications.
5) Management related risks: To handle the uncertain productivity of resources, the team makes sure that there are sufficient skilled staff and they have defined roles and responsibilities.
6) Socio-political risks: Socio-political risks include inflation, customs and import restrictions. The team can emphasize on using local firms/agents. To handle these issues, the team should have proper authorizations from the local administration and a contingency plan for possible inflations, which might be caused by a passed bill for change in taxations.

## Conclusions

Construction projects for the healthcare industry can pose various risks (Batalden et al. 2015; Talib and Rahman 2015). To avoid the risks during construction process, various rules and regulations must be followed strictly. Understanding project risks can help to manage them effectively. Risks are associated with technical aspects, business aspects or operational aspects of the project.

This research sheds light on the integration of expert knowledge with Monte Carlo simulations in a systematic framework to help project teams to understand the risk management plan pertaining to analysis results with the probabilities calculated from statistical evaluations. This paper shares the simulation process and results to provide a innovative and comprehensive risk-management program for healthcare projects. Although the common sources of risks in the construction projects change in the requirements and scopes, project teams should aware the appropriate definitions of local conditions, subcontractors, supply chain issues, design errors, roles and responsibilities.

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