Practical Analysis and Response for Risks Using Monte Carlo Simulation on Construction Manufacturing

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Abstract. This paper discussed a real project supporting the management of project risk. The model distinguishes between risks which have to be enhanced and risks which can be mitigated or accepted at some cost so that the customer requirements with respect to project completion time can be satisfied at a minimal cost. The model is based on risk management analysis processes and using a Monte Carlo simulation and in order to discover the probability to closure project within the expected date plan. The model is illustrated by means of a real-world case concerning a part of real state residential project construction located in the Republic of Iraq.

1. Introduction
Risk management in projects determines the types of risks that affect the project, describing them accurately, indicating the importance of each type, assessing the value of uncertainty, and indicating their impact on the project, and identifying the methods and procedures that efficient. The extreme strategy is reducing chances of these risks and not affecting the project, as well as monitoring and trying to control them by identifying these risks and designing appropriate plans to track and deal with those risks and follow up the possibility of establishing a new event and follow up in all different stages of the project life cycle.

In the risk management of projects, a variety of tracks, including the precautionary track, which includes measures to avoid the emergence of the quality of the risks associated with the stage of the work of the project and there is also a corrective track, which includes an adjustment in the course of work at a stage of the work of the project not only result Avoiding realized risks, but it also contributes to raising the level of work efficiency in the project. The risks of projects may be in the form of defects, failures or wastes in construction manufacturing that are discovered or occur during the execution of the project.

2. The main goals of the study
- Identify the risk on the construction project (case study)
- Identify the importance of a risk plan for construction manufacturing
- How to adopt or implement the analysis risk on projects
- Perform qualitative and quantitative risk analysis.
Collect the most important treatments and benefits for the implement risk response: Approaches, Techniques and Good Practices.

3. The scope
- If there is a project so the risks will be founded
- The risks categories are multi
- There are positive and negative risks
- Stockholder effect on occurring the risk and impacts
- OPAs Identification and environment
- OPAs Risk responses
- Monitoring the projects throughout executing the process

4. Overview of risk management
Risk management is the process of identifying, evaluating, and planning responses to events, both positive and negative, that might occur throughout the course of a project. Through risk management, you increase the probability and impact of opportunities on the project (positive events), while decreasing the probability and impact of threats to the project (negative events), [1].

Risks and their interactions can emerge at any time: at the front-end, during construction, or at the operation stage and build-up to shatter carefully laid plans. Indeed, the only certainty is that unforeseeable events will materialize. Uncertainty springs up as issues are brought to the fore, dormant tensions emerge, and interdependent links are triggered, [2].

5. Sources of risk
For owners or sponsors and even to contractors or subcontractors, unforeseen risks and unplanned may mean incurring losses that are not recoverable. In reality, there are no projects without risks throughout the project executing process, the project can be considered risky if the risks lead to the probability to:
- Over Budget
- Out of Scope
- Behind Schedule

6. Research methodology
A field study was conducted to identify the most important risks facing a strategic project in Iraq. Consider the risks identified as a research case and apply the concepts of risk management using the methods of analysis, risk response and control. The focus project in this research is part of the residential project in Iraq republic.
By identifying the project and the what the plan risks contained in the planning process and analysis the risks, the probability and impact and using Monte Carlo simulation method in quantitative it is the way that the research follows up to conduct and manage the risks in the current project.

7. Literature review
ISO Guide 73:2009 provides the definitions of generic terms related to risk management. It aims to encourage a mutual and consistent understanding of, and a coherent approach to, the description of activities relating to the management of risk, and the use of uniform risk management terminology in processes and frameworks dealing with the management of risk, [4].
Table 1. Sources of risk to the client’s business from construction projects, [3].

| No | Heading                          | Change and uncertainty due to                                                                 |
|----|---------------------------------|------------------------------------------------------------------------------------------------|
| 1  | Political                       | Government policy, public opinion, change in ideology, dogma, legislation, disorder (war, terrorism, riots) |
| 2  | Environmental                   | Contaminated land or pollution liability, nuisance (e.g. noise), permissions, public opinion, internal/corporate policy, environmental law or regulations or practice or ‘impact’ requirements |
| 3  | Planning                        | Permission requirements, policy and practice, land use, socio-economic impacts, public opinion |
| 4  | Market Demand                   | (forecasts), competition, obsolescence, customer satisfaction, fashion                          |
| 5  | Economic                        | Treasury policy, taxation, cost inflation, interest rates, exchange rates                        |
| 6  | Financial                       | Bankruptcy, margins, insurance, risk share                                                     |
| 7  | Natural                         | Unforeseen ground conditions, weather, earthquake, fire or explosion, archaeological discovery   |
| 8  | Project Definition              | procurement strategy, performance requirements, standards, leadership, organization (maturity, commitment, competence and experience), planning and quality control, programme, labour and resources, communications and culture |
| 9  | Technical                       | Design adequacy, operational efficiency, reliability                                            |
| 10 | Human Error                     | incompetence, ignorance, tiredness, communication ability, culture, work in the dark or at night |
| 11 | Criminal                        | Lack of security, vandalism, theft, fraud, corruption                                             |
| 12 | Safety Regulations              | (e.g. CDM, Health and Safety at Work), hazardous substances (COSHH), collisions collapse, flooding, fire and explosion |

In that Guide risk is defined as the “effect of uncertainty on objectives”. Guide 73 also states that an effect may be positive, negative, or a deviation from the expected, and that risk is often described by an event, a change in circumstances or a consequence, [5]. A guide to the project management body of knowledge (PMBOK guide) 2017 and all editions, provides risk management process overview respectively as below:

- Plan risk management
- Identify risks
- Perform Qualitative risk analysis
- Perform Quantitative risk analysis
- Plan Risk responses
- Implement risk responses
- Monitor risks

Because each project is unique, it is necessary to tailor the way project risk management processes are applied. Considerations for tailoring include but are not limited to:

- Project size,
- Project complexity,
- Project importance and
- Development approach.

8. Project Tailoring and consideration planning

Tailoring of the Project Risk Management processes to meet these considerations is part of the Plan Risk Management process, and the outcomes of tailoring decisions are recorded in the risk management plan, [6].
In practice, the plan of risks will be obtaining the purpose of the plan and the responsibly of the risk manager and the risk team members how will be managing the risk plan, the cost of creating the plan and risk contingency and finally the positive and negative factors. After the plan of the risks, the active step must identify the risks by holding the status meeting and using the available way in the enterprise the used usually like brainstorming method or SWOT analysis technique or expert judgment assist and documented on the special and professional way called risk register.

9. Risk register

It is the template outcomes from the identify risk process and it is containing the list of essential risks, list of risk responses, triggers and risk owners. The risk register will be updated during the risk management process to collect all variables and information of the risks and to make sure the plan is in scope and within the concept of risk responses.

The quantitative and qualitative risk analysis will be the below steps after identifying risks.

Table 2. Risk register output from the case study after the identified risk (own work)

| Doc title: risk register | PROJECT: Stage: creation |
|--------------------------|--------------------------|
| Process: identify risks  | Causes                   |
| Id | Details | Notes | Causes | Details | Notes |
| 1 | Delay of site mobilization | The unexpected obstructs it may delay the site preparation | The inaccurate estimation because of the huge amount of old building wastes in site | Focus in meeting |
| 2 | Delay to submittal the shop drawings | The contractor misunderstanding | Unclear details or complicated drawing or in a table of content | |
| 3 | Delay of approving the shop drawings from contractors | The ECG (CONSULTANT) maybe delay to adopt the drawings | 1.Needs More details 2.start the executing phase without vailed official document or sign contract | In case of and because the company has more than one project and the depending on some known sub-contractors |
| 4 | Water level problems on the excavation of foundations. | The site investigation mistakes in pre-project actives and allocates the level of water content. | Due to inaccurate points of the surveying the site investigations stage. |
| 5 | Bad or mistakes on the implementation (executing) phase. | The unsatisfied level of quality of finishing steps Due to the high-temperature rate in summer | The poor of qualified or craftsmen Foreigner groups to assets. |
| 6 | The climate and weather action on The site and work conditions | | The delay of the project schedule because of any effect or risks it makes the outside work on in summer more if it is not considered from the beginning. |
| 7 | The availability of material | The good quality materials availability | The Variety sources of the material suppliers and the increases of market orders on the building material Taking into account the banking facilitates for housing loans |
| Id | Identify risk                          | Details                        | Causes                                                                 | Notes                                      |
|----|---------------------------------------|--------------------------------|-----------------------------------------------------------------------|--------------------------------------------|
| 8  | Material incensement prices level     | More orders                    | New projects in processes (state projects and private).               |                                            |
| 9  | Increases of excavation cost          | The cost increases             | Due to a 4/or mistake in foundation depth related by site investigation or design issue |                                            |
| 10 | More time to implement excavation activity | Schedule delay effect     | Same as 9 causes                                                      |                                            |
| 11 | Project manager authority problems    | The intervention of the project manager decisions and authority from stakeholders e.g. sponsor or program manager | Unclear authority in the project charter or overlap authority.       |                                            |
| 12 | Terminate the project                 | Partly or full stop the project and terminated | Founding problems or owner decision.                                   |                                            |
| 13 | Procurements late supplying          | Late supplying the material    | Because of the routine administrative process                          |                                            |
| 14 | The mistakes on the site-built drawings will be few | Avoid the drawings problems as a positive point | The professional and qualified team in project management can avoid the most mistakes. | Lesson learned                             |
| 15 | Less price getting in executing phase | The chance to getting the lower prices in implement activates | The Investor decided to make a competitive between subcontractors by tendering. |                                            |
| 16 | Not respected the meeting time        | Not committed the meeting schedule | Irresponsibility                                                        |                                            |

In order to arrange the risks, classified them more accurately, focus and prioritize, probability and impact for the individual risks a qualitative risk analysis will be carried out and applied to the case of the study. The probability will be measured by designing the scale in order to know which is the likelihood of the risk occurring throughout the project life cycle, as below:

- **Very low** 1- 20 %
- **Low** 20- 40%
- **Middle** 40-60 %
- **High** 60-80 %
- **Very high up to** 80 %
### Table 3. Risk register update for the case study after the qualitative analysis (own work)

| Id | Identified risks                                                                 | probability | impact   | score          | categorization |
|----|----------------------------------------------------------------------------------|-------------|----------|----------------|----------------|
| 1  | Delay of site mobilization                                                      | Low         | Moderate | Low (threat)   | Executing/initiating |
| 2  | Delay to submittal the shop drawings                                             | Very low    | Moderate | Low (threat)   | Technical       |
| 3  | Delay of approving the shop drawings from the Consultant                          | Moderate    | Moderate | Moderate (threat) | Technical       |
| 4  | Water level problems on the excavation of foundations.                           | High        | High     | High (threat)  | Executing       |
| 5  | Increases of excavation cost                                                      | Low         | High     | Low (threat)   | Executing       |
| 6  | More time to implement excavation activity                                        | Very high   | Very high| Very high (threat) | Executing       |
| 7  | The availability of material                                                      | Low         | High     | Low (threat)   | Management      |
| 8  | Material incensement prices level                                                | Moderate    | Moderate | Moderate (threat) | Management      |
| 9  | Terminate the project                                                            | Low         | Very high| High (threat)  | Politics        |
| 10 | Bad or mistakes on the implementation (executing) phase.                         | Moderate    | High     | High (threat)  | Executing       |
| 11 | Project manager authority problems                                                | Low         | Low      | Low (threat)   | Management      |
| 12 | Not respecting the meeting time                                                  | Very low    | Low      | Low (threat)   | Management      |
| 13 | Procurements late supplying                                                       | Low         | High     | Moderate (threat) | Management      |
| 14 | Less price getting in executing phase                                            | Moderate    | High     | Moderate (opportunity) | Management |
| 15 | The mistakes on the site-built drawings will be few                              | Very Low    | Low      | Low (opportunity) | Technical       |
| 16 | The climate and weather action on site and work conditions.                      | Low         | High     | Moderate (threat) | Executing       |

The qualitative analysis of the risks in the project does not give a full indication of the risk level. Most of the departments of the projects like a (PMO) considered the risks to be converted into costs finally and even the risks of time and quality but the qualitative analysis located the trends for the analysis of risks either doing the quantitative for some of the high or very high risks or accept the current analysis. In case study, the quantitative risk analysis will be performed.
### Table 4. Risk register update for the case study after quantitative analysis and risk response (own work)

| Id | Identified risks                                      | probability | impact  | score  | response                                                                 |
|----|-------------------------------------------------------|-------------|---------|--------|--------------------------------------------------------------------------|
| 1  | Delay of site mobilization                           | 12%         | 60000   | 7200   | Active Communication with and prepare all required Equipment early       |
| 2  | Delay to submittal the shop drawings                 | 8%          | 40000   | 3200   | Collect all the information and consult to avoid the late               |
| 3  | Delay of approving the shop drawings from the Consultant.| 15%         | 100000  | 15000  | Prepare and sending early                                               |
| 4  | Water level problems on the excavation of foundations.| 75%         | 100000  | 70000  | Review the soil investigation report and hold a meeting with experts    |
| 5  | Increases of excavation cost                         | 11%         | 150000  | 16500  | More focus with the project team member and study the changes on dimensions and labour requests. |
| 6  | More time to implement excavation activity           | 30%         | 150000  | 45000  | Meetings with stakeholders especially the sub-contractors               |
| 7  | The availability of material                         | 5%          | 1000000 | 50000  | Prepare the orders and store the most critical material from the earliest stage of work |
| 8  | Material incensement prices level                    | 22%         | 1000000 | 220000 | Prepare the orders and store the most critical material from the earliest stage of work |
| 9  | Terminate the project                                | 5%          | 3000000 | 300000 | The contract conditions must be applying                                 |
| 10 | Bad or mistakes on the implementation (executing) phase.| 25%         | 500000  | 100000 | Monthly and weekly reports and make stats meeting to controlling         |
| 11 | Project manager authority problems                   | 15%         | 20000   | 3000   | Improving the active decisions meetings and give some of the delegations to the team member and good commutation with the portfolio manager. |
| 12 | Not respected the meeting time                       | 3%          | 10000   | 300    | Activate the other communication tools and send notifications about the next meeting early. |
| 13 | Procurements late in supplying                       | 10%         | 200000  | 20000  | Reduce the long retinue process                                         |
| 14 | Less price getting in executing phase                | 30%         | 800000  | 320000| Make a good chance as early to tendering the work from sub-contractors as a competitive opportunity |
| 15 | The mistakes on the site-built drawings will be few  | 5%          | 40000   | 20000(+)| Good teamwork and have a lesson learned                                |
| 16 | The climate and weather action on the site and work conditions.| 15%        | 50000   | 7500   | Arrange the daily work hours or make alternative work shafts            |
After quantitative risk analysis and calculating the threats and opportunity risks for the project. Risk responses should be planned and implemented not only for individual project risks but also to address overall project risk.

The same risk response strategies that are used to deal with individual project risks can also be applied to overall project risk: Avoid, Exploit, Transfer or Shear, Mitigate or Enhance, Accept, [6]. The main objective is to increase the level of control of risk, reduce the negative impact of the risk and remove as much as possible the potential impact. The measure becomes more effective when there is more control of one mitigation measure on one risk, [7].

The stage of assessment and analysis is the crucial mission of obtaining and select the factors and probability of occurrence the expected threats and their impact, by using the computer simulation it is the decision making and understands and it helps to get an indication by numbers.

| Table 5. Risk responses assessment and treatment (own work) |
|---|---|---|
| Id | Score | Risk responses |
| 1 | 7200 | Enhance 2000 |
| 2 | 3200 | Enhance 1000 |
| 3 | 15000 | Mitigation 5000 |
| 4 | 70000 | Mitigation 20000 |
| 5 | 16500 | Enhance 6500 |
| 6 | 45000 | Transfer 20000 |
| 7 | 50000 | Transfer 30000 |
| 8 | 220000 | Transfer 100000 |
| 9 | 3000000 | Accept 3000000 |
| 10 | 100000 | Enhance 20000 |
| 11 | 3000 | Enhance 1000 |
| 12 | 300 | Mitigate 100 |
| 13 | 20000 | Mitigate 10000 |
| 14 | 320000(+) | Enhance 450000 |
| 15 | 2000 (+) | Enhance 4000 |
| 16 | 7500 | Mitigate 3500 |

To complete the research study and achieve the simulation risk analysis the Monte Carlo simulation by using Primavera risk analysis are performed, in order to know the probability to complete the project within planned duration and cost, the probability was 80% to finishing the project within 21 months, and within the average percent to complete the project the duration are 19 months.

10. Risk controlling and updating
After accepting and responding to the actual risks identified in the previous risk management plan, risks must be monitored during project phases through pre-project lessons. Sometimes, additional risks arise
during the implementation of the risk response, which must be taken into account and accompanied until the project is exposed to additional uncontrollable risks that lead to increased cost or delayed project.

![Monte Carlo simulation](image)

**Figure 1.** Monte Carlo simulation

The aim of risk management is quantification of the undesirable, previously selected random factors, determination of their impact on time and cost of a construction project and the development of an alternative variant of realization, the actions minimizing damages or, for instance, the emergency time schedule, [8, 9].

The risk monitoring and control process, Figure 2 involves the identification, analysis, planning and tracking of new risks, constantly reviewing existing risks, monitoring the triggering conditions for contingency plans and monitoring residual risks, as well as reviewing the risk responses while evaluating their effectiveness. The process employs techniques which include variance and trend analysis, [10,11].

![Risk management process](image)

**Figure 2.** Monitoring and Control risks process,[10,11].

11. **Conclusions**

1. The brainstorming and meeting with expert's lesson learned and SWOT are active tools and techniques to make the initial proper risk on the planning project
2. One of an important issue is to provide a financial amount for creating an initial risk plan
3. There is unreality to expect to identify all risks can happen in a project from the planning process
4. The qualitative analysis is a trend to make more risk analysis by quantitative for high-level risks or to make treatment directly.
5. Throughout the responses and treat risks there is probability to appear new risks in executing phase.
6. In the time of the risk occurs actually on the project, it is late to do anything about it. That is why needing to plan for risks from the start and keep the reviewing of risk plan during project implementation.
7. Monte Carlo simulation can be trying a thousand or more probability to estimate the duration and cost as a result will be closer to reality taking into account the expected risk in the risk register.
8. The cost and duration of the project (case study) are influenced by all risks that documented in risk register on and the final probability was 80% to complete the project on plan.
9. The contingency or risk reserve must be more applicable at the execution phase to face any unlisted risk before.
10. The case study depends on the inputs information available from many sources collected in that time and the assessment of the risks as outputs study are dependent on the standard process (qualitative and quantitative) and simulate by Monte Carlo method, so it can be applied in another project case taking into account the variation of the inputs.

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