INVESTIGATING THE INTERRELATION OF COST RISKS IN LARGE-SCALE PROJECTS WITH A SYSTEM DYNAMICS APPROACH

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Large-scale projects are considered the riskiest projects due to their multidisciplinary nature and complexity. The main risk factors include a high project budget, technical challenges during project implementation that did not exist before, continuous project change orders, and environmental factors governing them. On the other hand, the project manager sometimes cannot correctly manage project risks and solve problems by applying traditional approaches despite spending enormous resources. Limitations of traditional risk management methods based on separate consideration of the impact of each risk and not considering the interrelations of risks, causal relationships between them, and the dynamic behavior of risk factors during the project lead project managers to resort to new methods such as dynamic risk management and the interaction of risks. Therefore, considering the number and position of large-scale projects within Iran and their role in economic and technical development, the present study is essential. In this study, by presenting a classified list of risks of large-scale projects, risks interaction will be identified, and then using the obtained relationships, we will present a dynamic model with the interaction of all risk factors on each other.

Keywords: Financial Risk, Complex Projects, Interdependency, Construction.

1 INTRODUCTION

Among the wide range of construction industry projects, large-scale projects are more critical because they consume a lot of time and cost, and because of the project’s unique nature, uncertainty is always the basis of risk management for a project (Mortazavi et al. 2020). Risk factors are present in every project, and risk management methods can create opportunities to avoid, mitigate, transfer, or accept serious threats, but in any case, they cannot be ignored (Taroun 2014). Risk factors significantly impact various project objectives, especially cost (Mortazavi et al. 2020). The mismanagement of risk factors, especially in large-scale construction projects, is a global issue due to cost overruns (Nasirzadeh et al. 2014). There is no one-size-fits-all solution to many of the problems that cause cost overruns. The proposed technical solutions must consider social, political, environmental, and other aspects and their interaction. Unforeseen side effects and the complexity of large-scale projects often lead to failure in engineering management (Sterman 2002).

Therefore, due to this feature of construction projects, engineering and management methods must include the coordination of complex and dynamic processes. By investigating previous studies, it is revealed that several studies have focused on different aspects of large-scale construction risk management. Limited research has examined the overall dynamics of these project risks and how dynamic risks interact with the project schedule and budget (Wang and Yuan...
Also, most research has been done on the risk management of construction industry projects in developed countries, but there is little information about managing cost risks in developing countries (Iqbal et al. 2015). After identifying the most critical cost risk factors in this paper, we propose a qualitative model with a system dynamics approach in large-scale projects in Iran, a developing country, to investigate the interrelations between risk factors.

This paper consists of a literature review accomplished in the following section. The next sections are the research methodology, and the qualitative SD approach demonstrated in detail. The fourth section implements the proposed qualitative SD approach to a hospital project, and varied elements affecting cost risks are modeled qualitatively. Finally, the conclusion is represented in the final section.

2 LITERATURE REVIEW

2.1 Dynamic Risk Management

The field of system dynamics, created at MIT in the 1950s by Jay Forrester, is designed to assist the project managers in learning about the structure and dynamics of the complex systems consisting of continued accelerated implementation and change (Sterman 2002). It is based on defining the essential components of a system, adjusting the causal relationships between them, and executing different scenarios for the future. It also simulates how the system reacts in the range of probability or uncertainty (Alkaissy et al. 2020). Due to the analysis of inter-relationships and feedback loops in complex systems, system dynamics modeling can result in highly dynamic systems that deal with time changes, nonlinearity, and feedback loop structures (Iqbal et al. 2015). Construction projects belong to the category of complex and dynamic systems because (1) very complex and interdependent components, (2) very dynamic, involving multiple feedback processes, nonlinear relationships, and the need for both hard and soft data (Nguyen and Ogunlana 2005).

Finally, in this paper, by studying the structure of risk factors in various articles and consultation with experts, the risk factors that affect the cost overruns were identified. Then, the most critical risk factors were extracted to investigate their interaction, which is shown in Table 1. Note that only the risks that affect the project’s cost and cause cost overrun are examined in this study.

<table>
<thead>
<tr>
<th>Code</th>
<th>Section</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Financial and economics</td>
<td>Delay in payment</td>
</tr>
<tr>
<td>2</td>
<td>Financial and economics</td>
<td>Inflation</td>
</tr>
<tr>
<td>3</td>
<td>Financial and economics</td>
<td>Exchange rate fluctuations</td>
</tr>
<tr>
<td>4</td>
<td>Financial and economics</td>
<td>Incorrect budget estimates</td>
</tr>
<tr>
<td>5</td>
<td>Financial and economics</td>
<td>Increasing material prices</td>
</tr>
<tr>
<td>6</td>
<td>Management</td>
<td>Poor coordination and communication</td>
</tr>
<tr>
<td>7</td>
<td>Management</td>
<td>Rework</td>
</tr>
<tr>
<td>8</td>
<td>Management</td>
<td>Delay in decision making</td>
</tr>
<tr>
<td>9</td>
<td>Management</td>
<td>Work packages trade-off</td>
</tr>
<tr>
<td>10</td>
<td>Management</td>
<td>Poor supervision of project supervisors</td>
</tr>
<tr>
<td>11</td>
<td>Management</td>
<td>Unrealistic schedule</td>
</tr>
<tr>
<td>12</td>
<td>Contractual and legal</td>
<td>High bureaucracy</td>
</tr>
<tr>
<td>13</td>
<td>Contractual and legal</td>
<td>Lack of transparency of the contract</td>
</tr>
<tr>
<td>14</td>
<td>Contractual and legal</td>
<td>Excessive inspection</td>
</tr>
<tr>
<td>15</td>
<td>Contractual and legal</td>
<td>Delays in resolving disputes and contract claims</td>
</tr>
<tr>
<td>16</td>
<td>Contractual and legal</td>
<td>Changes in tax regulations</td>
</tr>
</tbody>
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3 RESEARCH METHODOLOGY

This paper used a system dynamics approach to model cost risks in large-scale projects. As shown, some risk factors for cost overruns are considered first. These factors are qualitatively modeled according to the SD approach.

3.1 Identification of Different Elements Concerning the Cost Risk Factors

In the first step, several factors concerning the cost risk factors were recognized. These elements were determined by the literature review and consultations with the specialists associated with the hospital project (Nasirzadeh et al. 2014, Wang and Yuan 2017, Mortazavi et al. 2020).

3.2 Qualitative Model: Causal Loop Diagram (CLD) of Cost Risk Factors

In the second step, a dynamic model is used, applying feedback loops. The qualitative model helps to record the interrelationships and factors. Figure 1 shows the two types of arrows representing a cause-and-effect relationship between two variables, namely positive and negative (Xu and Zou 2021).

![Causal Loop Diagram](image)

When the causal relationship forms a closed loop (the arrow directions in the closed-loop must be the same), a feedback loop can be found. Feedback loops are divided into two types of positive and negative feedback. When the number of negative correlations in the feedback loop is an odd number, the negative feedback loop is considered (Figure 2). Otherwise, a positive feedback loop is considered (Figure 3) (Xu and Zou 2021).

![Negative Feedback Loop](image)

![Positive Feedback Loop](image)

4 MODELING

It was conducted at the Torbat Heidarieh Hospital in Iran to verify the qualifications of the suggested system dynamics model. The initial duration and cost of the mentioned project have resembled five years and $62 million, but there has been about 68 percent cost overrun in this project. The diverse elements affecting the cost overruns are determined in the next section. These characteristics are modeled using the SD method regarding their complicated interrelationships (Figure 4) that should be noted that the required initial data was collected based on the arguments of nine experts through interviews and questionnaires. This complex system is divided into three important sub-systems that are explained in the following.
4.1 Sub-System 1: The Financial and Economic Factors

The financial and economic sectors include five elements. The complicated interrelations that stand between these factors are depicted in Figure 5. For example, “inflation and early communication with them” will impact other factors authorized “delay in payments”. For example, “exchange rate fluctuation” will affect “material costs”.

4.2 Sub-System 2: The Management Factors

The qualitative model of different elements, including the management sub-system is represented in Figure 6. Regarding this figure, there are complicated interrelations between six elements. For example, “unrealistic schedule” affects the “work package trade-off”. It will also result in an increase in “coordination and communication among parties” involved in the project to improve “delay in decision making”. Finally, it will improve “rework” issues.

4.3 Sub-System 3: The Contractual and Legal Engagement

Finally, the complex interrelations of various factors related to contractual and legal issues are drawn in Figure 7. For example, it can be mentioned that “bureaucracy” concerns two factors, including “delays in resolving disputes” and “excessive inspection”.

Figure 4. The SD-Model of different elements impacting the cost overruns of large-scale projects.
5 RESULTS

By analyzing the model, it is found that computing for the complicated interrelations between different elements concerning cost overrun significantly impacts their prioritization. For this project, dynamics risk management optimized the cost overrun up to 40 percent. The professional experts could take the necessary executive actions with a mental model of cost risks are essential to gather input data for modeling cost risks using the suggested method.
6 CONCLUSION

There has been developing knowledge that the construction projects should be controlled by the cost overruns regarding risk factors of the whole project’s life cycle. This study displayed a System Dynamics approach to represent the interrelations of cost risk factors in large-scale projects to assess the proficiency of the suggested method; it was conducted at the Torbat Heidarieh Hospital in Iran. Firstly, the different elements affecting the cost overruns were recognized by the literature review and interviews with the experts involved in the project. Sixteen elements were determined founded on the arguments of a panel consisting of nine experts. After recognizing the different influencing elements on cost overruns, the qualitative model was produced applying cause and effect loops. The extended SD model was split into financial and economic factors, management considerations, and contractual and legal-related factors. The management sub-system has six critical factors, and due to the opinion of experts by control of this essential sub-system that plays a critical role for cost risk management, the project’s actual cost could be optimized up to 40 percent. The validation of the outputs was occurred by the experts of the project and compared with actual cost data. By investigating the results, it is found that using the suggested method, a set of complicated causal loops, and their visual illustration has a significant impact on risk factors prioritization and increasing proficiency, and control of the cost overruns of construction projects. Also, computing the complicated structure of different elements concerning project cost overrun may supply valuable information for managers and decision-makers.

References


