Proposing a Risk Management Model in Construction of Combined-Cycle Power Plant Projects

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Abstract. Companies are increasingly focusing on identifying risks and managing them even before they affect project executing. Risk management can play a key part in identifying problems and taking preventive measures in this regard. This research focused on risk management in the implementation of a combined cycle power plant project. This paper aims at exploring the role of risks and risk management practices in construction of this type of projects by considering how they can impact the project's time, quality, and cost. First, the project risk types were identified. The extent to which the project's objectives were achieved was then considered on the basis of three criteria: time, cost, and quality. Next, the risks were categorized and prioritized through a risk breakdown structure. The obtained results revealed the most influential risks in the project. Finally, the proposed risk management model was used in the project which led to strengthening the performance impact of risk management practices in the risky project environment.

Keywords: Project management, Risk management, combined cycle power plant (CCPP) projects,

1 Introduction

Electrical energy is the most convenient form of energy for most human uses. For this reason, demand for electricity is set to grow even further over the next few years. This research was focused on risk management in the implementation of Samangan combined cycle power plant (SCCPP) project. Samangan is the name of this project that located in Sirjan, Iran. The country's increasing demand for electricity has led to massive investment on building power plants. However, uncertainties, different layers of decision-making, and the increasing complication of technologies in this industry has created a multitude of risks and challenges in achieving the project's objectives [1]. The aim of project risk management is to decrease the likelihood of failure of the project. According to research, risk management in project portfolios must be carried out by adopting a broader standpoint than that of the individual risk in the project [2]. Managing the project risks is one of the main responsibilities of the project manager. However, if risk management has not been properly done from the start of the project,

the responsibility becomes complicated and even ineffectual [3]. The goal of this research is to identify and prioritize the risks and explore the role of risks and risk management practices in construction of SCCPP project in terms of their impact on the project's time, quality, and cost. Based on the proposed approach applied in this research, the risks involved in the SCCPP project will be identified and analyzed. So, the research question is, does the risk management model used in SCCPP project lead to strengthening the performance impact of risk management practices in the project risky environments? Through the remainder of the paper, the relationship to industrial and service systems, literature review, methodology, case study, and the finding sections will be presented respectively. The paper continues with results, main discussion, and lastly, research conclusions.

2 Relationship to Industrial and Service Systems

The power generation industry and its service sectors are going through profound transformation towards digitalization and integration of new levels of smartness. Risks have significant impacts on power generation projects' execution, systems, products, value chains, and business models, including exceeding the estimated cost, failing to complete the project in the due date, and decline in quality and productivity. Considering the large amount of investment required in these projects, failing to reach the time, cost, and quality objectives in power plant projects can cause huge financial losses. This shows the importance of risk identification and management in this industry which is requiring increased level of real time data availability and exchange to continuously monitor and control risk changes and support smart risk plan implementations facing mostly human skills and knowledge deficiencies, improper contracts and import constraints and sanctions.

It is quite characteristic that electric power industry, as a key part of economy in any country, has a deep and versatile effect on the performance of industrial outfits. The power sector appears to be a crucial factor in enhancing universal corporate competitiveness and a driver of economic development [4]. So, in order to ensure the stepwise integrated growth of the power sector, it is essential to create an efficient sectorial risk management system to enable the power generating firms to instantly identify and minimize the influence of appearing threats [5]. This case study is carried out on a CCPP project by Mapna Group in Samangan project. Mapna is an umbrella name for a group of industrial companies tasked with construction and installation of power generation equipment, including wind, steam, and gas turbines, electrical generators, heat recovery steam generators, electrical and control systems, conventional boilers, and railway locomotives.

3 Literature Review

Risk management is indeed a fundamental component of project management. Many research projects have been conducted with different methods in various domains focusing on risk management. The results of these studies led to a categorization of

risks within this domain. Nie et al. launched an interval-stochastic method for risk management to consider the notion of risk in stochastic programing and to control the resource cost variability. The model was formulated to identify the optimal power generation mix for Beijing's energy system. The obtained results revealed that the decision makers' risk attitude along with the inherent uncertainty of system components can significantly affect the power-generation schemes, the city's energy supply, the probabilistic penalty, and the system's total cost [6]. A new financing tool called hybrid bond was introduced by Lee and Zhong to launch projects related to renewable energy. The instrument can support the initial capital costs, and manage the risks involved in renewable energy investment [7]. Serpella et al. considered two kinds of risk management techniques: preventive risk management techniques applied prior to the start of a project to manage anticipated risks that are likely to occur during the execution of the project; and remedial risk management techniques used during the project's execution phase when a risk has occurred already [8]. Gatzert and Kosub identified recurrent risks and presented risk management solutions to be applied in renewable energy projects with the aim of identifying critical gaps in risk transfer, and thereby distinguishing between offshore and onshore wind parks with focus on the European market [9].

Hwang et al. investigated risk management in small scale projects in Singapore with respect to barriers, status, and the impact which risk management can have on project performance. They provided a detailed explanation of risk management in those projects and marked the main benefits of risk management for small projects participants [10]. Desai and Kashiyani reviewed construction projects works exposing the knowledge about Insurance as a risk management instrument in construction industry [11]. More recently Cheraghi et al. established a mathematical programing model for choosing risk response strategies in construction projects. The presented model is centered on the project classical triangle of time, quality, and cost in order to find the best risk response strategy in construction projects [12]. Liu and Zeng used the system dynamics method to study the risks involved in renewable energy investment. The results showed that the investment in the early developmental stage was mainly affected by policy risk, that gradually declines the same as technology risk, while market risk gradually becomes the main uncertainty that affects the investment in the mature developmental stage [13]. Qazi et al. considered identifying the critical risks and selecting appropriate risk mitigation strategies as decision problems at the start of a project, taking account of the decision maker's utility function regarding the significance of project goals and the holistic interaction between project risk and complexity [14].

Carvalho and Rabechini exposed how risk management contributes to project success, taking into account the contingent effect of project complexity [15]. Violante et al. highlighted the difficulties small construction companies have dealing with risk management and tried to describe how they manage risks and which aspects of their practice in risk management can be enhanced [16]. Titarenko et al. described the statistical and probabilistic methods applied in managing the investment risks in construction projects and emphasized the necessity of adopting robust procedures when dealing with conditions of significant uncertainty [17]. Reddy attempted to gain a general understanding of risks and their consequences in construction projects and the process through which they are managed. The impact of risk on project

assessment is discussed as well as the risk management instruments and methods in construction industry [18]. Zhao et al. identified the critical obstacles to enterprise risk management implementation in Chinese construction companies and explored the interrelationships amongst these obstacles [19]. Kang et al. studied the current status of risk management practiced in the Malaysian construction industry in an attempt to assess the process, as well as the various techniques and tools currently used to manage the projects [20].

4 Methodology

As exposed, there are various risk management models for construction projects. Despite the considerable differences among them, they are all applied to serve the same purpose reduce or prevent negative results on the project objectives. In this study the risk management proposed model was carried out using the project operational requirements into account. The manner of directing risk management activities in the project was defined in risk management planning. Next, different types of risks involved in building power plants in the company's projects were identified based on experts' opinions, modeling, and examining previous projects. In this phase, which is referred to as risk identification, a list of events that might probably occur was developed. The project's success was then assessed on the basis of the three criteria of time, execution quality, and cost. Mahjoub et al. examined the role of strategic talent management in project success, considering the organizational commitment, job satisfaction and motivation as mediators [21]. The prioritization of the risks for further analysis and evaluation was carried out combining each probability of occurrence and their impact. The Probability and Impact Matrix, which is a prevalent risk analysis tool, was also used in this study. The impact of each risk will be separately examined using the probability and impact matrix; however, a simultaneous risk affects of the three criteria of time, quality, and cost of the project was also undertaken. In this research, the quantitative method for data collection were applied using interviews and questionnaires conducted by different project managers and experts (45 experts). First, the experts working on the sites of the projects, and the experts working in the project's central office were identified. The experts all had more than 12 years of experience in risk management and executing power plant construction projects with bachelor or master degree. The closed interviews have been conducted with the average duration of 30 minutes. The whole interview process took about 5 weeks.

The first and second levels of the risk breakdown structure of the SCCPP project is shown in Fig. 1 which represent an organized and hierarchical illustration of the main potential risks of the project, ordered in the form of sets and subsets. Generally, there are different classifications of the risks with regards to the project's objectives. So, the risk breakdown structure helps to identify the causes of occurrence and the sources of different types of project risks, if categorized according to their potential source of occurrence.

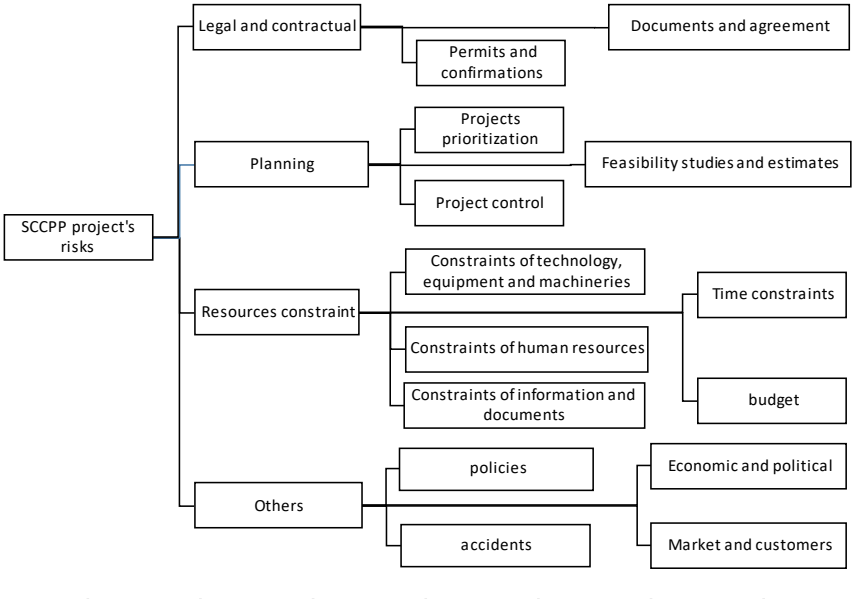

Fig. 1. The SCCPP project's risk breakdown structure

5 The SCCPP Case Study

The manner of directing the risk management activities in the SCCPP project was determined through risk management planning. Considering the fact that there should be no power outage throughout the power grid, projects must be conducted immediately within high quality level requirements, and based on the estimated cost. Therefore, the main goals of the projects under investigation pertained to quality, cost, and time. Hosseini et al. suggested a multi-objective mathematical model to discover the optimal balance amongst time, quality, and cost of construction projects which involved using reinforced concrete in underground structures according to existing risks [22]. It should be noted that the importance of these goals vary according to the type and nature of the projects and their particular circumstances.

The main phases of the SCCPP projects are as follows: preliminary studies, selection and occupation of land, selection of a consultant and signing a contract, selecting a contractor, project execution, pre-commissioning, commissioning, and final delivery. The nature of the problems in CCPP projects is generally related to investment, high technology, and high volume of projects. Zohrehvandi et al. proposed a procedure for going through the closing process group in mega projects. This research was done on a CCPP project as a case study [23]. Some experts believe that in risk management process, the most important phase is risk identification.

Stosic et al. addressed the improvement of innovation project risk identification by applying Risk Breakdown Structure methods, and present a follow-up analysis of the subject [24]. The major output of this phase is identification and categorization of the risks and their sources. In this paper, the parties involved in the projects including the employers, contractors, supervisors, and consultants were interviewed with the aim of identifying the risks. The documents produced in the previously conducted projects were also examined in order to determine the reasons why some projects' objectives were not met. They were also studied for benchmarking purposes.

The examination of the SCCPP project led to the identification of a few risks, and each risk was assigned to a subset of the already prepared risk breakdown structure based on its source. In fact, Fig. 2 shows a more detailed level of risks compared to Fig. 1. In order to manage and properly confront the identified risks, they must then, categorized in order of importance. In this way the more serious risks, and their impacts in a greater focus on projects' risky aspects and parts, will be exposed. The methods of risk analysis and assessment are generally classified into two main groups: qualitative and quantitative methods. In qualitative risk analysis, typically the risks are categorized according to their probability of occurrence and their possible impact on the project, measured through a descriptive or relative approach. Therefore, qualitative approaches are a suitable tool for ranking and determining the relative priority of the risks for further actions. Therefore, in this research, the quantitative method for data collection were applied detailed in next section.

6 SCCPP Study Main Findings

Kırılmaz and Erol investigated the supply chain risk management process and suggested a procedure in the risk mitigation phase. The model was tested and analyzed by Probability and Impact Matrix [25], which is a prevalent risk analysis tool, also used in the case. This approach considers the probability of each risk and its possible impacts on project goals with respect to time, quality, and cost. In order to determine risk significance and its impact on project objectives, the risk assessment or Probability and Impact Matrix is applied. This matrix helps to determine the combination of probability and impacts in a way that the risks can be categorized in low, medium, and high-priority risks.

In this research, questionnaires were designed to gather the required data and information from SCCPP project experts and stakeholder and a quantitative method for data collection were applied. The risks impact on the criteria were examined through a five-point Likert scale (ranging from too little to too much). As an example, Table 1 shows the ranking of the risks impact on project duration.

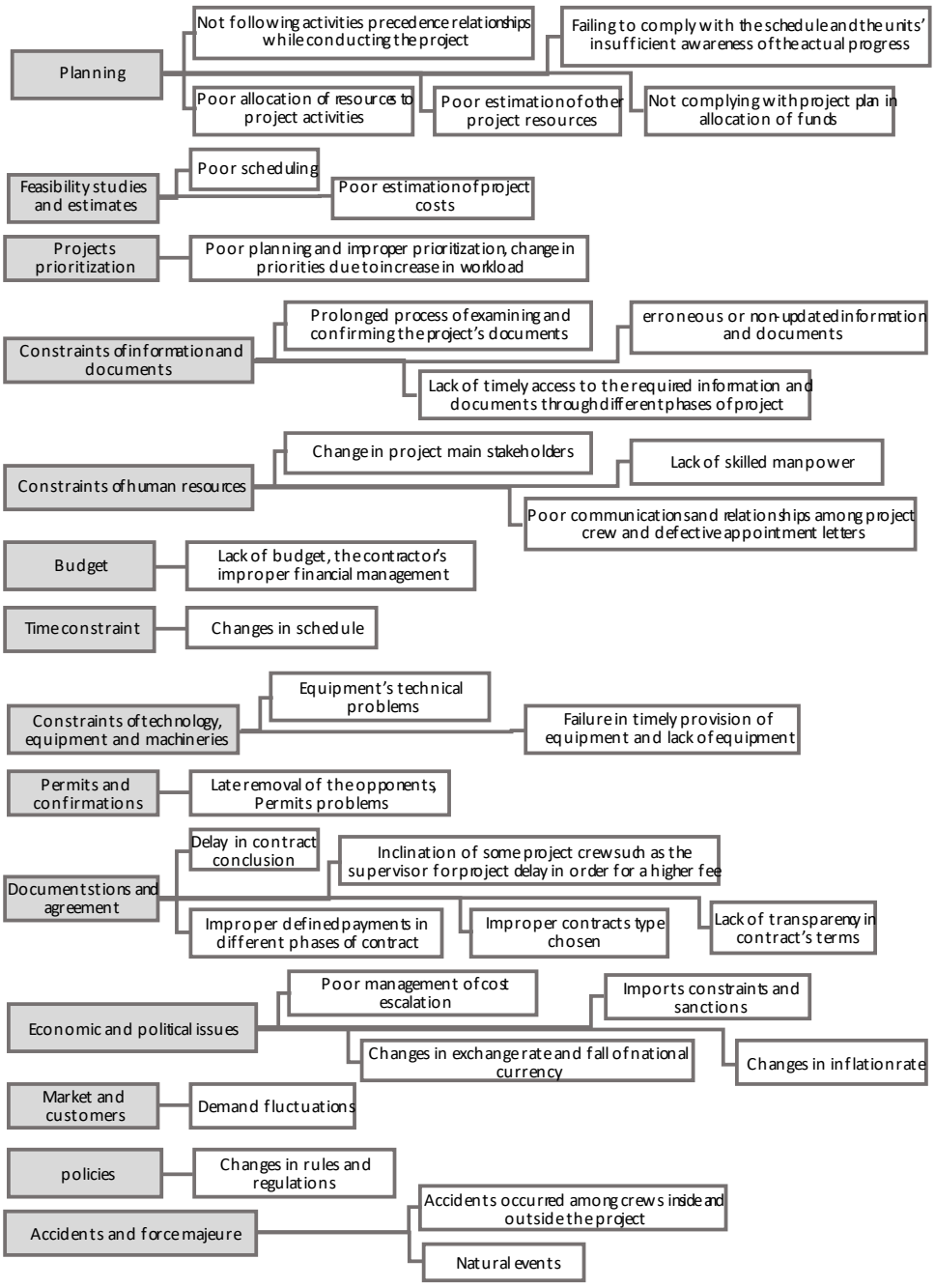

Fig. 2. SCCPP identified project risks

Table 1. SCCPP project's risk impact on project duration

Risk impact	Numerical values	duration increase
Very Low	1	Less than 10%
Low	2	10 to 20%
Moderate	3	20 to 35%
High	4	35 to 50%
Very High	5	More than 50%

It must be mentioned that the risks are mapped in different areas of the matrix according to the average value obtained from each criterion and the explanation of each area. The probability-impact matrix with regard to project duration for the SCCPP is shown in Fig. 3 Similar diagrams were also developed for the other two selected criteria

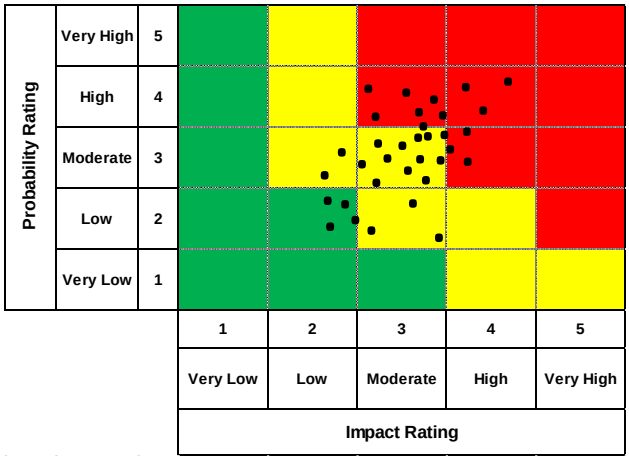

Fig. 3. SCCPP project probability-impact matrix

As shown in Fig. 3, the red area represents the highest risks: the green area represents lowers, and the yellow area represents moderate risks. A risk with a high and very high probability of occurring and which will have a high impact on the project objectives will likely need further quantitative analysis and response plan. As also if a particular risk has a moderate probability with a higher estimated impact. A risk with a low and very low probability of occurring and which will have a low impact on the project objectives so no response plan will be developed. According to the probability of risks occurrence and their impact on SCCPP project duration, about 36 percent of the identified risks are in the area of high-priority, 48 percent in the area of medium- priority, and 12 percent are in the area of low-priority. This distribution shows that most of potential project risks might threat the project with completion delays. Pfeifer et al. created an optimization problem to maximize project delay due to

certain stochastic task disruptions, and proposed a genetic algorithm to identify the critical tasks which may cause the maximum risk of delay in the project [26].

The probability and impact matrix examines the impact of each risk separately; however, a risk simultaneously affects the three criteria of project time, quality, and cost. Based on the specific conditions of a given project, one criterion of assessing a project's success might be considered relatively important. In these cases, the assessment and analysis of the risks impact on the project success criteria must be conducted simultaneously. Weighting is one of the common ways of performing multiple criteria analyses and determining the relative significance of variables in decision making. Normalized weighting was applied in this research to determine the relative significance of risk assessment criteria. Table 2 shows the relative weighting of the three criteria, determined according to interviews and questionnaires carried out by different project managers and experts as mentioned in methodology section.

Table 2. Relative significance of risk assessment criteria in SCCPP project

Impact of risk on project Quality	Impact of risk on project Cost	Impact of risk on project Duration
30%	33%	37%

To determine the risks' priority and final ranking, the average points of each criterion was multiplied by its weight, and the products were added together. The risks were divided into three groups of medium priority, high priority and low priority based on their final rankings. Also the obtained results show that the problems posed by the stakeholders match the rankings to a great extent. In SCCPP project, Lack of skilled manpower, Improper contracts type chosen and Imports constraints and sanctions are the high-priority risks according to Fig. 4. Therefore, a smarter planning is deemed necessary to resolve these issues.

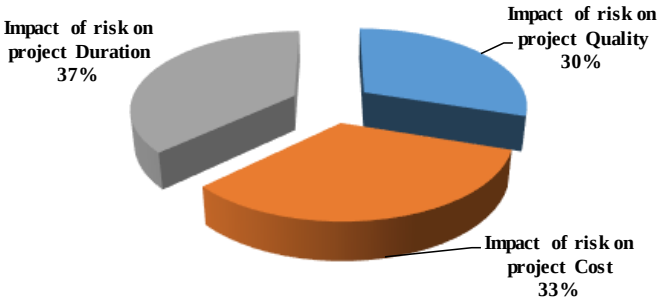

Fig. 4. The relative weighting of the three criteria

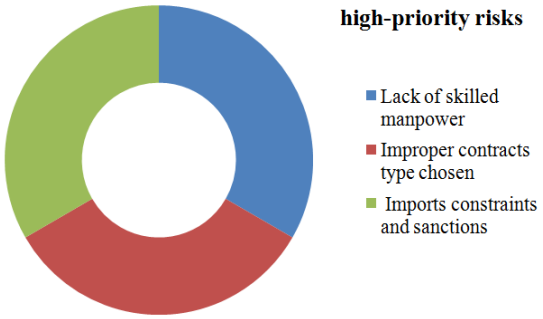

Fig. 5. The high-priority risks in the project

7 Main Conclusions

Risk management is a process through which the threats to an organization's earnings and capital are identified, assessed and controlled. The main purpose in risk management is to understand, analyze, and address risk in order to make sure that organizations and firms achieve their objectives. The goal of this study was to identify and prioritize the risks and explore the role of risks and risk management practices in construction of SCCPP project in terms of their effect on the project's time, quality, and cost. As a part of the project risk management process, different types of risks were identified after the planning phase of risk management. The results of these examinations led to making the projects' risk breakdown structure in groups of planning, resource constraint, legal and contractual and others. Each of these main groups were classified into subgroups. The identified risks were put in their respective groups. The results indicated that in SCCPP project, significant risks such as Lack of skilled manpower, Improper contracts type chosen and Imports constraints and sanctions were among the high-priority risks which. Considering the results of this study project managers and stakeholders should take appropriate measures to reduce the undesirable risks' impacts by this risks developing proper mitigation risk strategy plan development in order to achieve project higher resilience on SCCPP projects. Eventually, according to the research question, SCCPP project complemented and strengthened the performance impact of classical risk management practices in risky environments. For future research, the scope of the study can be expanded to examine the risk management of similar projects in different countries. It is also suggested that the handling of risk management in other types of projects be considered seriously by academics and project practitioners as an area in need of further research.

Acknowledgements

The authors are grateful to all of those with whom they had the pleasure to work during this and other related projects. This work has been partially supported by UNIDEMI - Research and Development Unit for Mechanical and Industrial Engineering by the Portuguese FCT-PEST program UID/EMS/00667/2019.

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