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Improvising Construction Supply Chain through Risk Assessment

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Abstract - *The purpose of this research is to improvise the CSC by identifying several factors affecting Supply Chain Management implementation in construction projects, which, once implemented, would assure effective Supply Chain Management in the construction industry. Due to the inherent complexity and complex linkages between various parties associated with the construction operation, construction projects face several dangers throughout their lifecycle. The major risk factors in the execution of a construction supply chain are identified in this article. This paper identifies the key risk factors in implementation of construction supply chain. With all of these considerations in mind, a research study concentrating on supply chain management implementation in the construction industry was conducted. A checklist and a questionnaire survey were used to perform the research. Based on prior investigations, a hierarchical structure was created to identify risks. To analyse the risks and priorities them for future investigation, a probability and impact matrix, a popular qualitative tool, was used to evaluate them. Data analysis techniques such as single factor ANOVA test, chi-square test are adopted for data analysis. As the high risks were identified, appropriate responses to deal with each of them in the event of their occurrence were proposed in the final stage.*

Key Words: Supply chain management, Construction industry, Risk management, Construction projects, Mitigation, etc.

1. INTRODUCTION

Construction industry is one of the oldest industries on the planet, and it is known for being conservative and immature in many areas, including information technology, innovation, and supply chain management (SCM). The construction industry and its supply chain are beset by a slew of issues, all of which have dire consequences. The supply chain is defined as "the network of organisations that are involved in the various processes and activities that produce value in the form of products and services in the hands of the ultimate customer" through the upstream and downstream linkages (Christopher ,1992).

To advance and expand the construction industry, it is important to enhance communication and, in particular, supply chain integration. Since the construction industry is such an important social and economic operation in every country, SCM strategies are thought to be effective in rising the competitiveness of construction firms and the construction sector as a whole. Engineers, contractors, suppliers, and clients all play important roles in establishing and developing SCM and collaboration in the construction industry. The building sector in India faces multiple problems, the most significant of which is an inefficient material supply chain in construction. Every product that reaches a client is the result of the combined efforts of several businesses. A supply chain is the term used to describe all of these organisations. Procurement of supplies, transformation of raw materials into finished products, and distribution of final products to clients are all part of the supply chain network of companies and business processes. The integration of suppliers, distributors, and customer logistics into a single process is known as supply chain management.

2. METHODOLOGY

In this research work, qualitative method of analysis, as a cost-effective, popular method, among the companies was chosen to be employed. A successful qualitative assessment can be obtained by data collection and documenting them for further analysis. The surveys participants will be asked to evaluate the risks occurrence probabilities, along with their impacts on the project's cost, quality and timing. The identified risks in the project are qualified, and the likelihood of their occurrence and consequences are analysed as if they actually occurred, using this procedure. This system is highly beneficial when there is a deficiency of required numerical data as well as time and financial constraints (Radu, 2009). The method's limitation is the inaccuracy of data required to provide an accurate analysis. It is critical to give accurate, dependable, and high-quality data, as well as an acceptable actual knowledge of them, in order to conduct a valid analysis. Qualitative analysis can lead to more accurate complete quantitative analysis or even risk response planning on its own. According to PMBOK (2017), following stages have been designated to perform a qualitative analysis correctly. These stages are described briefly in the following sections.

Risk Probability and Impact Assessment: The possibility of the identified risks occurring, as well as the risks' potential consequences on project objectives, are

assessed at this stage. The project's objectives include cost, schedule, performance, and quality, and the analyzed implications on them include both positive and negative risks (Cooper et al., 2005). The impacts and probability of occurrence are used to rank the risks. In this step, two sorts of ranking are used. Ordinal scales that categories risks as very low, low, moderate, high, and extremely high. Cardinal scales that assign numbers to the probability and consequence of risks (i.e. 1, 2, 3, 4, and 5).

Table 1: Scale of probability (PMBOK, 2017)

Probability	Very Low	Low	Moderate	High	Very High
Risk Event	1	2	3	4	5

Table 2: Impact scale on time, cost and quality (PMBOK, 2017)

Identified Risk	Project Objective	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Risk Event	Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time increase	>20% time increase
	Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost increase
	Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

Risk management strategies should also specify and accept the scales. In short, each detected risk can be analysed using checklists, questionnaires, and interviews, and then the level of its impact and probability can be established (Tabanfar, 2014).

Probability and Impact Matrix: The risk is prioritized using a likelihood and impact matrix. Risks are prioritized according to their likelihood (PMBOK, 2017). The importance of each risk is depicted in the matrix by assigning a rating and a colour (Westland, 2007). Multiplication of values of risk occurrence probability and its repercussions are the matrix's constituents, as illustrated in equation.

$$Total\ risk\ score = \text{Probability} \times Impact$$

The compiled results of probability and impact are shown in the matrix in Figure

	Threats					Opportunities				
5	5	10	15	20	25	25	20	15	10	5
4	4	8	12	16	20	20	16	12	8	4
3	3	6	9	12	15	15	12	9	6	3
2	2	4	6	8	10	10	8	6	4	2
1	1	2	3	4	5	5	4	3	2	1
	1	2	3	4	5	5	4	3	2	1

Impact

Figure 1: Probability and impact matrix

Risk ratings can be done separately for each project aim, as shown in Figure 2.9. (cost, time, etc.). Threats and opportunities are dealt with in the same matrix, with varying levels of definition used. Organizations classify risks in multiple categories, usually three categories, based on risk scores, to decide on risk responses (PMI, 2008):

- Red: Indicates high risk, high impact on objectives, and high probability of occurrence.
- Yellow condition: Indicates risks with a significant impact and probability.
- Green label: A green label indicates that the risk has a modest impact or is unlikely to occur.

Risk Mitigation: Risk mitigation stage is mainly dealing with deciding about the methods of managing and responding the risks properly. Several risk response techniques are available according to Project Management Institute's (PMI) A Guide to the Project Management Body of Knowledge (2017) which are adopted in this work. After identifying and analyzing potential risks, the next stage is to respond to them (Tummala & Schoenherr, 2011). This stage is primarily concerned with developing an effective response strategy with the goal of minimizing potential risks as much as feasible. Mitigation refers to the process of implementing risk responses, monitoring risks, detecting new threats, and analyzing them (Tabanfar, 2014). Supply chain management can be divided into two categories: supply risk management and demand risk management. While supply chain management focuses on network planning, partnerships, transportation, and logistics, demand risk is a different issue. Management is responsible for forecasting demand, planning, and inventory management.

There are various risk response approaches, four of which are described below: avoiding, transferring, mitigating, and accepting.

- Avoid: This refers to safeguarding the project and removing dangers.
- Transfer: This indicates that the threats' effects are being passed on to a third party.
- Mitigation: Mitigation is the process of reducing the impact of hazards or the probability of occurrence.
- Accept: This refers to accepting risks and taking no substantial action until the risk happens.

3. RESULTS

The techniques used for statistical analysis are discussed in this chapter. These techniques are considered to have

a significant impact on the suitability of the end results. Checklists and questionnaire surveys were chosen as the primary data gathering methods in this study, as previously stated. The simplicity, quickness, and cost-effectiveness of the procedures are the grounds behind these decisions. Summary of results, from checklists and questionnaire surveys will be presented in this chapter, from each respondent's point of view. Statistical analysis has also been done on the raw data.

Table 3: Risk priorities, considering overall risk scores

No.	Type of Risk	Risk factor	SCM sub-context	Average of Risk Scores Overall
1	Strategic	Lack of knowledge regarding CSC	Lack of knowledge regarding CSC	17.75
2	Supply	Poor SCM relationship with the supplier	Supply reliability	14.69
3	Supply	Absence of conflict resolution process	Trust	14
4	Operation	Insufficient training and instruction	Knowledge transfer	13.88
5	Strategic	Organizational culture	Organizational culture	13.56
6	Operation	Supplier related operational factors	Cost benefits	13.54
7	Supply	Poor SCM relationship with the supplier	Support from top management	13.4
8	Supply	Poor SCM relationship with the supplier	Mutual business planning	12.98
9	Supply	Restricted Selection of suppliers	Experience	12.79
10	Supply	Absence of conflict resolution process	Relationship development	12.61
11	Operation	Supplier related operational factors	Standardization of processes	6.77
12	Supply	Restricted Selection of suppliers	Geographic location	6.14
13	Strategic	Deficient functions of internal organization	Inventory	5.92
14	Strategic	Deficient functions of internal organization	Purchasing	5.83
15	Supply	Restricted Selection of suppliers	Market reputation	5.73
16	Strategic	Deficient functions of internal organization	Storage	5.65
17	Operation	Supplier related operational factors	Simplifying construction process	5.56
18	Supply	Restricted Selection of suppliers	Price	5.48
19	Strategic	Deficient functions of internal organization	Transport	5.38
20	Supply	Restricted Selection of suppliers	Recommendation	4.93
21	Supply	Lack of Communication	Integrated information system	4.81
22	Operation	Insufficient training and instruction	Organizational culture	4.5
23	Operation	Poor IT support	Lack of IT support	4.48
24	Supply	Lack of Communication	Free flow of information	4.46
25	Operation	Supplier related operational factors	Better quality service	4.1
26	Operation	Supplier related operational factors	Simplifying the ordering process	4.06

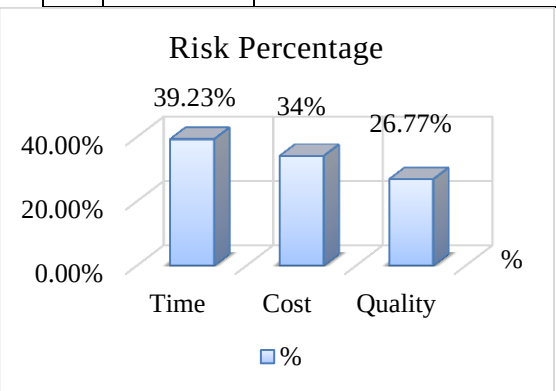

Figure 2: Total risk percentages (Time, Cost, Quality)

1. Total risk percentages of Time - 39.23%
2. Total risk percentages of Cost - 34%
3. Total risk percentages of Quality – 26.77%

• Risk Response

It's fairly evident that the final level of risk assessment is the process of determining strategic options and action plans for dealing with risks and reducing their potential threats to project objectives. When confronted with dangers, a broad response approach is often chosen, according to literature. Accepting, transferring, avoiding, and minimizing the repercussions or likelihood of risk occurrence are the strategies. According to the results of

a questionnaire study, the majority of participating construction organizations use frameworks to respond to risks.

4. DISCUSSIONS ON RESULTS

This chapter mainly includes the results obtained from checklists and questionnaire surveys carried out, and discussion will be made on them. In the first section, discussions will be done on results of questionnaire survey, which revealed the following information:

4.1 Discussion on the Questionnaire Survey Results: Discussions on three different parts of the questionnaire will be done in the subsequent sections.

- Background information
- SCM relevance
- RM relevance

Background Information: It is necessary to start the questionnaire survey with general questions, not the explicit questions about objectives, to ensure participant's correct field. Questions 1 to 5 are mainly about the respondents and his/her company's basic information.

SCM Relevance: SCM relevance was focused in questions 6 to 13. Separately, questions 6, 7 and 8 concentrated on implementation of SCM and its effect on time, cost and quality of the projects. Being asked about these concepts, nearly all of the respondents had agreement on positive effect of SCM implementation on time and quality, and all of them had agreement on the positive effect of SCM implementation on cost.

Question 9 was about showing the level of relationship between construction team and clients, or vendors. Regular monthly meetings are being held between the majority of survey participants (50%) and their clients or vendors. Question 11 was about the basis of choosing vendors and suppliers, showing that selecting them is mostly based on recommendations. In question 12, the relevance of SCM to the respondents' businesses were asked. According to replies, most of them were involved in SCM-related businesses. According to question 10, the most important internal organization functions in SCM are listed as below, according to their importance:

- Purchasing
- Transport
- Storage
- Inventory

Question 12 was aimed at surveying the relationship with the clients, and the important factors of SCM in this relationship. From the results, the factors, in the order of importance are:

- Cost benefits
- Better quality service
- Standardization of processes
- Simplifying the ordering process
- Simplifying the construction process

The effective important factors in relationships of construction supply chain were asked in question 13 that are listed from the highest importance to lowest, as:

- Frequent meetings
- Integrated information system
- Support from top management
- Mutual business planning
- Free flow of information
- Trust
- Supply reliability

Risk management relevance was investigated in questions of 14 to 16. Various tools and techniques are being employed to identify the risks threats and opportunities. These tools were investigated in question 18. Results are listed as below.

- Documentation reviews - 23%
- Checklist analysis - 25%
- Risk Breakdown Structure (RBS) - 13%
- SWOT Analysis - 10%
- Questionnaire Survey - 13%
- Failure mode and effect criticality analysis (FMECA) - 5%

Among the methods, checklist analysis and documentation reviews were employed more frequently than the other methods.

4.2 Discussion on the Checklist Results: In this section, qualitative analysis results obtained from checklists will be discussed comprehensively. According to the statistical analysis results explained in the previous chapter, for time, cost and quality, 9, 9 and 3 high risks were identified respectively along with 10 high risks affecting project objectives in overall case. As comparison was done among the objectives' risks and the overall ones, the whole identified risks of time, cost and quality were included in the overall case risks. Considering this mutuality, totally 10 cases were the high risks, which are originated from five major risk factors:

- Lack of knowledge of CSC
- Absence of a conflict resolution process
- Old organizational culture
- Insufficient training and instructions
- Poor SCM relationships with the supplier

In addition, according to the results of qualitative analysis, the negative risks affecting time had greater shares. In the successive stages, there are risks affecting cost and quality consecutively.

Framework for Risk Response Strategies: Based on the previous studies and the participant responses, a framework will be proposed to find an adequate and efficient risk response, to cope with identified high risk factors. This practical framework addresses the following analysis fields: Risk Effects on the CSC (Construction Supply Chain) Project: A set of categories, including macro-effects relevant to failures have been identified, to keep them within the estimations of cost and time and to attain the expected and required

performance (PMI). There are two main aims associated with this classification: firstly, by means of grouping the risks effects, the critical managing aspects will be revealed to the managers and secondly, to direct the risk quantification phase, by the categorization, to determine the impact of risk factors properly (Aloini et al., 2012 a).

Responsibility of the Risk Factor: From risk management viewpoint, it is fundamental to identify the participants or parties who are responsible in decision making process and required authority to determine, control and manage the risk factors. Major participants in CSC are stated to be the general contractors, designers, clients or owners and suppliers. Designation of each one's responsibility is as essential point to achieve a suitable distribution of profit margins. As a result, properly assigning duties and giving personnel with distinct understanding is critical to completing project activities (Aloini et al., 2012 a).

Limitation: This approach seeks to identify the nature of risk influences by distinguishing subjective and objective constraints. Objective constraints are caused by environmental concerns or construction properties in general, whereas subjective limitations are caused by a lack of perception. Obviously, different constraints demand different approaches to confront and manage risks (Vrijhoef & Koskela, 2000).

Strategies for Negative Risks or Threats: As previously stated, there are four common techniques for dealing with risk threats (negative consequences): avoiding, mitigating, transferring, and accepting. Each one must be chosen based on the risks' impact on objectives and probability of occurrence, and each has its own distinct impact on risk scenarios. Mitigation and avoidance are suitable ways, particularly for significant risks with large consequences, but the other two methods (accepting and transferring) are particularly appropriate for less critical, low impact threats (PMBOK, 2017).

Risk Response and Treatment: In this section, explanations will be given for the appropriate responses and techniques adopted against the high-ranked risk factors using the framework proposed in the preceding section, as well as the survey participants' suggestions and experiences.

4.2.1. Lack of knowledge of CSC: Reduced margins for equipment maintenance, strong profitability through low real costs, long-term project planning and coordination, increased tolerance from delivery facilities, and frequent pairing with progressive clients are all advantages of supply chain management in construction. However, supply chain management in the construction industry is complicated and incorporates numerous factors. Construction supply management includes, some of its responsibilities, and the advantages of applying supply chain management in the construction industry. For effective implementation of CSC awareness about advanced supply chain management trends is must. An organization should conduct expert lectures, training programs, SCM software sessions, etc. regularly. Systematic SCM practices should be adopted in major construction organizations and for that specialized personnel should be employed.

4.2.2. Absence of a conflict resolution process: In this study, the absence of a conflict resolution process risk factor, flaws in partnership performance, vendor managed inventory, material and information flow integration, and communication are considered as the foundation. In terms of consequences, insufficient coordination, a lack of knowledge sharing, and the misappropriation of technology can be identified. The risk factor is a subjective limitation with a decisional level of the operation stage, and it is the responsibility of all project participants, including the client or owner, contractor, designer, and supplier. Mitigation is well-known as the best way to deal with this risk. Information and communication technologies are considered the finest available tools for mitigating risk and associated challenges, particularly in the use of SCM techniques, and providing effective communications throughout the chain.

4.2.3. Poor SCM relationships with the supplier: This risk factor can cause flaws in relationship development, strategic alliances, lean thinking, and concurrent engineering, all of which are sub-contexts of this risk factor. The supply chain is defined as a network of companies linked by upstream and downstream relationships and engaged in a variety of activities such as creating goods and services and distributing them to clients. Late involvements can be linked to a variety of factors. One of the most important is the lack of regular (or irregular) meetings between the network's various elements. This risk occurrence can lead to ineffective synchronization, a lack of integration, additional expenses, and wasted time.

4.2.4. Insufficient training and instructions: Due to a lack of knowledge that may result in repeating cycles, adopting advanced project training may improve organizational performance. Unexpected effects, such as unmet customer requests, time waste, poor project description, missing information, design adjustments, and reworks, may occur if the indicated faults and changes are not found and rectified immediately. Designers, contractors, and clients/owners are all responsible parties in this risk. The sensitivity of plans to errors and modifications will be decreased as a result of these measures, ensuring that performance and anticipated schedules are maintained.

5.2.5. Old organizational culture: Limitations in the integration of materials and information flows, vendor maintained inventories, and communication, which are considered as sub-contexts of this risk in this study, are the cause of this risk. Because of the high group of

potential suppliers on the market, every firm uses software to organize and record the relevant documents and information. The format of the files produced by each program varies. Format conversion is an essential procedure in order to keep sharing and exchanging the necessary information and documents. It's tough to use them because of variations in formatting approaches in existing documents. As a result, there is a limit on how existing information can be used in a document in the future. To deal with this risk factor, the best strategy is to avoid it by using international standardization. Businesses can profit from merging their various Enterprise Resource Planning (ERP) systems in order to reuse data in Business Process Re-engineering (BRP) and create more rational and efficient functioning operations.

5. CONCLUSIONS

The construction industry is known for being a low-productive, highly fragmented, time and cost overruns, and conflicted sector in comparison to other industries. Besides that, due to the large amount of money invested in this industry, it is always regarded as a high-risk venture, especially given the characteristics mentioned. Supply chain management is now viewed as an innovative tool for resolving these issues, allowing for new creative solutions.

Risk has a negative meaning in the supply chain, and is defined as an uncertain event that, if it occurs, will have unanticipated negative consequences on operations and objectives. The supply chain risks management process is known to be a minimizing technique for dealing with these factors. It is defined as the process of identifying potential risks in an organization, analysing them, and deciding how to respond to them. The supply chain risk management in the construction industry was investigated in this study. The first step of identifying risks was completed by reviewing and categorizing relevant articles. Hierarchical classification of identified risks was conducted in the following stage, as per risk breakdown structure (RBS). Following the completion of the previous stage, a checklist was created that included the identified risk factors, risk types, and SCM sub-contexts. Simultaneously, a questionnaire survey was created to determine how well respondents understand the concept of construction supply chain risk management. In addition, because of its relative rapid speed the qualitative analysis method was used to evaluate the identified risks. The probability and impact matrix was selected as a popular qualitative tool for assessing and prioritize the risks for this analysis. Finally, the higher risks were forwarded to the response planning stage, which took proper measures.

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