

Project Study for Supply Chain Risk Management: A Digitalization-Based Analysis from The Perspective of The General Contractor

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Abstract—The construction industry faces numerous supply chain risks that can significantly impact project cost, schedule, quality, and overall performance. These risks arise from factors such as material shortages, supplier disruptions, transportation delays, inaccurate information flow, and market uncertainties. With the increasing complexity of construction projects, traditional supply chain management approaches are often insufficient to effectively identify, assess, and mitigate these risks. Digitalization has emerged as a transformative solution, enabling better visibility, coordination, and decision-making across the supply chain.

This study examines Project Supply Chain Risk Management (PSCRM) through a digitalization-based approach from the perspective of the general contractor. The research focuses on identifying major supply chain risks encountered during construction projects and evaluating how digital technologies can enhance risk management practices. Technologies such as Building Information Modeling (BIM), Internet of Things (IoT), artificial intelligence (AI), cloud-based platforms, and data analytics are analyzed for their role in improving supply chain transparency, communication, real-time monitoring, and predictive risk assessment.

The study adopts a comprehensive review and analytical framework to assess the relationship between digitalization and supply chain risk management performance. Findings indicate that digital technologies significantly improve risk identification, information sharing, supplier coordination, and project resilience. Furthermore, digital integration enables general contractors to proactively respond to disruptions, reduce uncertainties, and enhance overall project efficiency.

The research concludes that the adoption of digital tools and data-driven strategies is essential for effective supply chain risk management in modern construction projects. The study provides valuable insights for contractors, project managers, and industry stakeholders seeking to improve supply chain performance and achieve

successful project outcomes in an increasingly digital construction environment.

This paper addresses the topic of Project Supply Chain Risk Management (PSCRM), a subject that has received limited attention in the existing literature. It introduces the concept of the Project Supply Chain (PSC) and explains that most research has focused primarily on the Construction Supply Chain (CSC), which is designed exclusively for project implementation in the construction sector. Construction Supply Chain Risk Management (CSCRM) is acknowledged as a relatively young field of study; however, an increasing number of publications are exploring CSCRM in greater depth, highlighting areas that remain underexplored or insufficiently examined. The paper points out that the concept of PSCRM is not yet clearly defined in the literature and that effective risk management in this context requires dedicated tools and measures. One such measure proposed for use in the PSCRM process is the Foster-Hart measure, which allows for the quantification of risk levels and can be employed to prevent bankruptcy an advantage not offered by other commonly used risk measures. Furthermore, the paper attempts to define PSCRM by synthesizing insights from the literature on traditional supply chains (SCs). The concept of supply chain risk is also discussed. The final section of the paper explores the role of digitalization in PSCRM, a perspective rarely addressed in the current literature. In discussing the digitalization of PSCRM, the use of advanced information technologies is emphasized, alongside the necessity of well-prepared data to support the PSCRM process although this requirement may pose significant challenges.

I. INTRODUCTION

Project supply chain risk management is a critical aspect of construction project success. General contractors are responsible for coordinating suppliers, subcontractors, manufacturers, and logistics providers

to ensure timely delivery of materials and services. However, supply chains face numerous risks such as delays, cost overruns, quality issues, information gaps, and disruptions caused by economic, environmental, or technological factors. Digitalization offers innovative solutions to identify, assess, monitor, and mitigate these risks effectively.

This paper focuses on PSCs, the concept of which is indirectly derived from the CSC. An effort was made to describe such a chain, and then to characterize the project supply chain risk management (PSCRM) framework, primarily from the perspective of the general contractor (GC), which is the most important link in such a chain. It is worth mentioning that literature does not define the concept of PSCRM and does not present its theoretical framework. The concept of risk within the project supply chain analyses and the Foster-Hart risk measure, which was treated as an element influencing the functioning of such chains, were also presented. Furthermore, it was pointed out that the risk of the PSC is reduced by digitalization. This is the subject of the final considerations of this paper, as well as the approach to risk analysis for the entire PSC, which is carried out by GC using appropriate IT systems. This paper uses the literature on the subject, against the background of which scientific reflection is made. His state of affairs resulted from the fact that broadly understood cooperation quite often resulted in potential benefits that companies would not have gained on their own. At this point, one can also mention, for example, that synergy effects are often observed in business practice. Synergy in the supply chain is a phenomenon in which team cooperation of companies generates additional value that exceeds the sum of the individual efforts of each member. In other words, the effect of synergy is to increase the potential of the entire supply chain. Moreover, a group of links cooperating with one another becomes more competitive and, as a result, wins the fight for the customer. All this has led to an increase in interest in the concept of the supply chain, which has resulted in the appearance of numerous publications that have contributed to the accumulation of a relatively large scientific achievement. Despite this fact, the theoretical foundations of supply chains still cannot be considered closed issues. There is a lack of scientific research on the management of project supply chains (PSCs), which is visible even in the small number of works

devoted to this issue. Moreover, there is also a lack of research related to project supply chain risk management (PSCRM), because most of it concerns supply chain risk management (SCRM). Therefore, any work on these two issues can be considered attractive not only for theoreticians but also from a practical perspective. This work is devoted to the latter issue, based on classical theories related to SCRM, against the background of which the reflection is made. The work uses literature on not only classical supply chains, but also project supply chains, because these two types of chains are to some extent similar to each other. It cannot be omitted that in the case of the construction sector, researchers noticed the difference in the concept of the supply chain, using different nomenclature and using the concept of construction supply chain (CSC), mainly to emphasize this difference. It was noticed that the implementation of the new concept of supply chain management in construction is completely different, both in terms of pace and degree of difficulty. In other words, researchers consider three types of chains, similar in some respects and different in many.

II. PSC VERSUS CSC IN CONSTRUCTION SUPPLY CHAIN

Aspect

PSC (Project Supply Chain)

CSC (Construction Supply Chain)

Definition

A supply chain specifically organized for a particular construction project.

The overall network of organizations involved in supplying materials, labor, equipment, and services to the construction industry.

Scope

Limited to a single project and its lifecycle.

Broader and covers multiple projects and long-term industry operations.

Focus

Project-specific objectives such as cost, time, quality, and risk management.

Industry-wide procurement, logistics, supplier relationships, and resource management.

Duration

Temporary; exists only until project completion.
Continuous; operates across multiple projects over time.

Participants

Client, general contractor, subcontractors, suppliers, consultants, and project stakeholders.
Manufacturers, distributors, suppliers, contractors, logistics providers, and industry stakeholders.

Risk Management

Focuses on project-related risks such as delays, material shortages, and coordination issues.
It addresses broader risks, including market fluctuations, supplier reliability, transportation disruptions, and regulatory changes.

Digitalization Role

Uses BIM, IoT, AI, and project management systems to manage project-specific risks.
Uses enterprise systems, supply chain analytics, digital procurement, and industry-wide information platforms.

III. OBJECTIVE

Successful completion of a specific construction project.

Efficient functioning and sustainability of the entire construction supply network.

Capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in Despite this, the division seems to be logical and allows for conducting numerous studies cognitively interesting not only from the point of view of supply chain management but also from the perspective of risk and its minimization. It can therefore be assumed that construction supply chains are a network of many organizations and relations between links, which includes various flows, e.g., information, materials, services, products, and financial, mainly between the client, GC, and other links [33]. As can be seen, the word "construction" is not included in this definition, because it is assumed that the construction perspective is obvious here. In the case of a PSC, it can be assumed that it is a large global network used to deliver a large project, and this network consists of many links. These include, for example, the GC, suppliers, subcontractors, etc. [21].

Although the above definitions do not exhaust the matter, it can be assumed that they are precise enough to be used in theoretical considerations. Marcin Halicki et al. / *Procedia Computer Science* 270 (2025) 2715–2724, 2717 Marcin Halicki et al. / *Procedia Computer Science* 00 (2025) 000–000. 3 is related to the nature of the supply chains presented in the work. At this point, it is worth referring to the risk that always accompanies the functioning of all economic entities, including various versions of supply chains. PSC and risk – a project-based approach In the case of project supply chains, it should be noted first of all that they are not a single flow chain (of materials, products, information, financial resources, etc.) but a network of many organizations, also including relationships that concern this flow, taking into account that the broadly understood integration of the PSC is part of project supply chain management [1, 10]. A similar view can also be found in another work, which states that in the case of project supply chain management, the focus is mainly on the internal integration of the chain [15]. The analysis of the literature related to supply chains allows us to conclude that along with the departure from the basic form and the transition to project forms, which are also related to the implementation of construction projects, risk management can be treated as a process. This process is not only related to the links but also increasingly to the implemented project, primarily concerning the GC. It cannot be ignored that literature refers to risk management mainly from the perspective of classic or construction supply chains, describing risk, for example, in supply chains in construction. The poor literature on the subject complicates the considerations related to the analysis of the functioning of project supply chains, as well as those related to risk assessment. Suffice it to say that the number of works devoted to this topic is small. As a result, it is impossible to find a precise definition of PSCRM. However, one can reflect on the poor literature. For example, it is quite common to believe that supply chains built for projects are exposed to problems related to the implementation of projects, and yet they were created precisely for them, e.g., disruptions in projects are becoming frequent [10]. These disruptions result from the lack of perspective on such entities as a whole. For this reason, it is necessary to first identify the risk, within which the causes of its occurrence should be noted, which are referred to as "risk factors." In summary, literature

research allows us to identify various risk factors to which project supply chains should respond [1]. These include, for example, an inappropriate IT system, an inappropriate selection of suppliers, inappropriate communication, and late involvement of links in the supply chain. The listed risk factors can be considered in the category of stimuli because project supply chains can respond to them appropriately, for example, by avoiding risk and then controlling and stopping it. However, there may be so many risk factors that it is not always possible to avoid risk, while its control should be something natural within the framework of risk management. However, knowing that the PSC is a creation established for the implementation of the project, for the delivery of which the GC is responsible, it can be put forward that the project risk management process for the PSC should consist of five stages:

Risk management planning by the GC, • Identification of risk factors and opportunities that may affect project implementation; • Analysis – to determine whether the project can be implemented by the PSC; • Risk response planning; • Implementation of response and risk monitoring in the PSC.

IV. THE ANALYSIS OF PSCRM

The risk analysis for the entire project is carried out by the GC with the help of appropriate IT systems. This is also appropriate insofar as the GC bears the risk of contract fulfillment and may also offer financing. The overall risk is the weighted sum of the individual risks. In addition to the GC, each supplier in the chain could also calculate its own risk on the basis of its own data and the data of its own suppliers. For the risk analysis and assessments, the own Foster-Hart values and those of all suppliers are therefore included at each level and in particular for the GC. This makes it relatively easy to determine the overall Foster-Hart value of the GC. However, the risk should not only be determined singularly at the beginning of the project but should also be tracked on an ongoing basis. Predictions are also required for this. Supplementary IT-based analysis methods can be used to further increase validity. For example, Failure Mode and Effects Analysis (FMEA), Hierarchical Cluster Analysis, and Loss Distribution Approach (LDA) are used to determine the risks for each participant; Extended Performance Analysis and Principal Component

Analysis are suggested [17], but these can be time-consuming. The use of risk simulations in which, for example, changes in Foster-Hart values for all suppliers are determined on the basis of statistical distributions appears to be more significant [23]. Currently, the use of artificial intelligence appears to be the most promising, particularly for forecasting [13, 17, 22]. Overall, it can be stated that the digitalization of PSC as a whole and risk management in particular appears to be absolutely essential in order to ensure the functionality of PSC and PSCRM and to make it possible in the first place. This obviously generates considerable added value for GC. The prerequisite is an appropriate IT solution for recording and analyzing risks. An initial concrete technical idea has been outlined here and will be further detailed below. that may affect the flow of materials, information, equipment, and services throughout a construction project's supply chain. Effective PSCRM is essential for ensuring project success in terms of cost, time, quality, safety, and sustainability.

Risk Identification

The first step in PSCRM is identifying potential risks that may disrupt project activities. Common risks include:

- Material shortages and price fluctuations
- Supplier or subcontractor failure
- Transportation and logistics delays
- Poor communication among stakeholders
- Design changes and scope variations
- Quality issues in supplied materials
- Regulatory and environmental constraints
- Natural disasters and unforeseen events

Risk Mitigation Strategies

General contractors can implement various strategies to reduce supply chain risks:

- Selecting reliable suppliers and subcontractors
- Maintaining safety stock of critical materials
- Diversifying supplier sources
- Establishing long-term supplier partnerships
- Developing contingency plans
- Improving contract management practices
- Enhancing communication and coordination mechanisms

Role Of Digitalization In Pscrm

Digital technologies significantly improve supply chain risk management:

a) Building Information Modeling (BIM)

- Improves project visualization and coordination
- Reduces design conflicts and rework
- Enhances supply planning

b) Internet of Things (IoT)

- Enables real-time tracking of materials and equipment
- Provides monitoring of storage and transportation conditions
- Improves logistics efficiency

V. CONCLUSION

PSCRM is a critical component of modern construction project management. By integrating digital technologies such as BIM, IoT, AI, cloud computing, and data analytics, general contractors can identify risks earlier, improve supply chain visibility, and respond more effectively to disruptions. As construction projects become increasingly complex, digitalized PSCRM provides a strategic advantage by enhancing efficiency, resilience, and overall project performance.

So, there is a lack of historical data, and the results cannot be generalized. Fourth, PSC can often be built for the implementation of a project with a confidentiality clause, so access to empirical data will be impossible. Fifth, the number of works devoted to PSC is still small, so the accumulated knowledge is still poor, and there is a lack of theoretical frameworks that would support research. For this reason, many cognitive gaps can be found, and this article aims to fill one of them. With all this in mind, an attempt was made to characterize PSCRM and the digitalization approach. An attempt was made to build an original definition of PSCRM, based on the collected knowledge resources, revealing the fact that the literature on risk management focuses on CSC, divided into a general perspective and a green perspective. In the case of PSCRM, a Foster-Hart measure of riskiness was indicated that can be used to assess the risk level because its main feature is that it allows avoiding bankruptcy in the long term. Other known measures do not have such a feature. An

example method for calculating its value was also shown. Additionally, an attempt was made to characterize the digitalization of PSCRM, which is related to the use of information technologies, often based on newer technologies. It was justified that the risk management process should be based on the use of appropriate data, although it may be associated with numerous problems, because such an approach may be difficult to implement. Based on the digitalized approach, it was found that the total risk for PSC, and therefore not only for GC, can be calculated based on data, but the high degree of complexity of the calculation means that IT support is also required to calculate the total risk. Therefore, a sample risk assessment scheme is graphically shown, taking into account the central risk database. This will allow for proper analysis and risk assessment in order to reduce it. PSCs are very important for large-scale projects and are particularly affected by risks because risks at every stage of the SC can contribute directly to the failure of the overall project. For this reason, a standardized definition and dedicated risk management for PSCs appear to be absolutely essential. However, there are still no complete concepts for this. However, the essential prerequisite for risk management reporting across the entire PSC is a standardized database that is available at all times. As a serial transfer from stage to stage obviously takes too much time and is associated with inconsistency risks, the central PSCRM database proposed here seems unavoidable. However, such systems do not currently exist as standard and would therefore first have to be established. While this appears conceptually unproblematic in principle, technical problems may arise, particularly with regard to possible system compatibility, as well as skepticism on the part of all participants in the SC due to the additional work involved. As suitable risk management across the entire PSC also appears unavoidable due to legal requirements for risk management systems, suitable, flexible, efficient, and low-cost PSCRM systems should be developed or quickly integrated into existing risk management systems. To sum up, the analysis of the literature allows us to assume that there are many challenges in the field of risk management in PSC. However, this topic is so underestimated and superficially treated that the characteristics of the most important areas of knowledge related to broadly understood risk seem to be necessary to systematize this knowledge, especially

since risk is a concept that is not only ambiguous but also controversial. For this reason, the issues presented in the work can be considered for further research that will concern PSCRM.

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