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Review

A Conceptual Framework for Implementing Lean Construction in Infrastructure Recovery Projects

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Abstract: Natural hazards can have substantial destructive impacts on the built environment. Providing effective services in disaster areas is heavily reliant on maintaining or replacing infrastructure; thus, post-disaster reconstruction of infrastructure has attracted growing attention. Due to the complex and dynamic nature of infrastructure recovery projects, contractor companies engaged in this work have typically experienced poor performance. Furthermore, from a commercial perspective, the post-disaster reconstruction environment is characterized by fierce competition and market uncertainty, challenging the organizational resilience of companies undertaking this work. One approach for improving contractor performance is the implementation of lean construction, but the literature lacks consensus on its capability to affect organizational resilience. To respond to this problem, a conceptual framework applicable for lean implementation in infrastructure, which explicitly addresses organizational resilience, is required for recovery projects. In parallel, contributing components to effective implementation of lean-recovery and supportive theories for justifying the conceptual framework must be identified. Consequently, this paper proposes a conceptual framework to implement lean practices for the enhancement of organizational resilience. The framework is developed using a systematic research method, wherein 110 research documents were discovered initially, and following processing, 18 relevant documents were identified and analyzed. Through this process, contingency and Transformation-Flow-Value (TFV) theories were identified as an appropriate foundation for a framework to implement lean construction in infrastructure recovery projects.

Keywords: lean construction; contractor performance; organizational resilience; contingency theory; TFV theory; infrastructure recovery projects; lean recovery; post-disaster reconstruction; systematic; literature review

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1. Introduction

In recent decades, there has been an increased incidence of natural hazards and extreme weather events across the world [1]. Such disasters, including floods, bushfires, hurricanes, and earthquakes, have had significant destructive impacts on society, the economy and the built environment. For example, in the last decade, 1.7 billion people globally have been affected by weather-related natural hazards, and natural disasters have led to a loss of over 410,000 lives [2]. According to the United Nations Office for Disaster Risk Reduction, economic losses associated with these natural hazards have cost over US$520 billion globally and forced around 26 million people into poverty [3]. Exacerbating this situation, natural hazards cause significant disruption of civil infrastructure, undermining reconstruction of disaster areas and causing long-term economic damage and social disruption. For example, the 2016 Kaikoura earthquake in New Zealand caused extensive damage to the infrastructure across the northeast of the South Island. In particular, transportation infrastructure was severely affected, including the destruction of over 350 km of state highways, and substantial impact on the railway network that led to the cessation of freight transportation between Christchurch and Picton for over 10 months [4]. Consequently, a priority for post-disaster recovery projects is infrastructure, such as roads, water, rail and telecommunication networks, which provides the backbone of modern societies and economies [5].

A key contributor to effective post-disaster recovery processes for infrastructure is the construction company. They provide support with logistics, resources and the workforce [6] to manage reconstruction projects and restore damaged infrastructure. Despite being in such a critical role, the environment these companies operate in is far more complicated than that of conventional construction projects, due to uncertainties around disaster conditions [7]. These conditions pose various threats to performance and undermine resilience [6,8]. Specifically, poor performance of construction companies is common in recovery projects [9], resulting in delays and cost overruns [10]. Such performance issues and associated risks threaten the resilience and competitiveness of these companies in the volatile construction market, leading to their failure in recovery projects [11]. Consequently, construction companies are required to be resilient to manage infrastructure recovery projects. If not, their failures can lead to even more adverse social and economic impacts in areas already suffering from natural hazards.

One effective method for improving the performance of construction companies is the adoption of lean methodologies to improve contractor performance indicators such as cost, quality, and time [12]. Lean has proven to be effective for supporting project performance improvement measured against a wide range of indicators including cost and time performance indicators [13]. A growing body of literature acknowledges the use of lean principles in improving organizational performance [13,14]. However, despite the ongoing development of specific lean methodologies in various domains, their relationship to organizational resilience remains poorly understood, especially in recovery projects. This suggests the urgent need for research on two related topics.

First, there is a lack of understanding of the contributing components needed for the effective implementation of lean construction in infrastructure recovery projects. Habibi Rad et al. [15], for example, note that there is insufficient evidence about which lean construction tools and techniques can enhance contractor performance in infrastructure recovery projects and organizational resilience of construction companies is missing from their decision-making procedures. Such research identifies the need for systematic theoretical development. Second, the theories and evidence relating to these contributing components must be positioned in a conceptual framework to provide a repeatable system for implementation.

The present paper responds to these two needs by undertaking a systematic literature review (SLR) to identify and analyze the contributing components and underlying theories required for the effective implementation of lean construction in infrastructure recovery projects. It also explores inconsistencies and gaps in the literature and reveals future research needed to address them. Through this process, a conceptual framework is proposed for a lean implementation to enhance organizational resilience and contractor performance within the post-disaster recovery projects domain. Two research questions were developed to shape this research:

RQ1. What are the contributing components to the effective implementation of lean construction in infrastructure recovery projects?

RQ2. Which theories provide support or justification for effective lean construction implementation to enhance organizational resilience in disaster risk management research?

The paper is structured as follows: Section 2 describes the research methodology; Section 3 presents the findings associated with contributing factors in and an overview of theories of effective lean implementation, followed by a discussion of contractor performance and organizational resilience within post-disaster recovery research contexts; Section 4 discusses the proposed conceptual framework; and Section 5 reports the conclusions.

2. Materials and Methods

This research adopts the SLR method, which is a reliable and well-defined methodology that follows a rigorous sequence of phases to develop robust outcomes [16,17]. The SLR method has previously been used to examine lean implementation [11,15,18,19] and provide answers to specific research questions. An SLR entails five stages: (i) question formulation; (ii) exploring the literature; (iii) study collection and assessment; (iv) analysis; and (v) reporting of results [16].

The first stage involves developing research questions to help reach the study's objectives. The second stage is associated with determining the source's location for investigating the literature. Although opinions about research databases vary, there is consensus about the accuracy of the Scopus and Web of Science databases for this procedure [20]. Thus, the current study uses both databases for accuracy and reliability. Google Scholar was also employed as a supporting tool to avoid missing relevant literature and enhance the findings' reliability.

The time span designated for the SLR was from 2000 to December 2021. The justification for choosing 2000 as the initial point was that the discussion on incorporating lean and resilience paradigms can be dated back to this year [21]. For an SLR, appropriate keywords must be selected. The preferred keywords and search terms were categorized into three groups, 'column (1)', 'column (2)' and 'column (3)'. Column (1) has keywords pertinent to lean construction and its synonyms: 'lean principles' and 'lean production'. Column (2) comprises the most frequent keywords associated with performance, such as 'contractor performance', 'project performance' and 'construction performance'. Finally, column (3) comprises 'resilience', 'resilient' and 'organizational resilience'. The search terms employed were comprehensive, so as not to restrict the search, while sufficiently targeted to answer the twin research questions framed in this paper. The terms were used to identify papers by title, abstract and keywords.

The third stage, study collection and quality assessment, applies inclusion/exclusion criteria and categorization. The exclusion criteria were planned around lean and resilience theoretical concepts by considering performance-based approaches. Thus, papers lacking coverage of these notions were excluded. Those papers that did not concentrate on the theme of resilience and lean in construction (for example, by examining lean in health care, genetics and agriculture domains) were eliminated. Only English language papers with full text were analyzed in this study. This was to ensure that thorough and consistent content analysis could occur to determine how the papers responded to the research questions for the current study. The inclusion benchmarks provide further assistance for the selection process. For example, research results only contained peer-reviewed journal papers and proceedings of international conferences, since these are the most trustworthy for SLR purposes [22].

Data analyses were conducted in the next stage employing content analysis approaches [16]. Finally, the collected data—identifying both contributing components for the effective execution of lean construction and theories used to support and justify the conceptual framework—were analyzed to answer the two research questions posed in this paper. Figure 1 summarizes the SLR process for the current study.

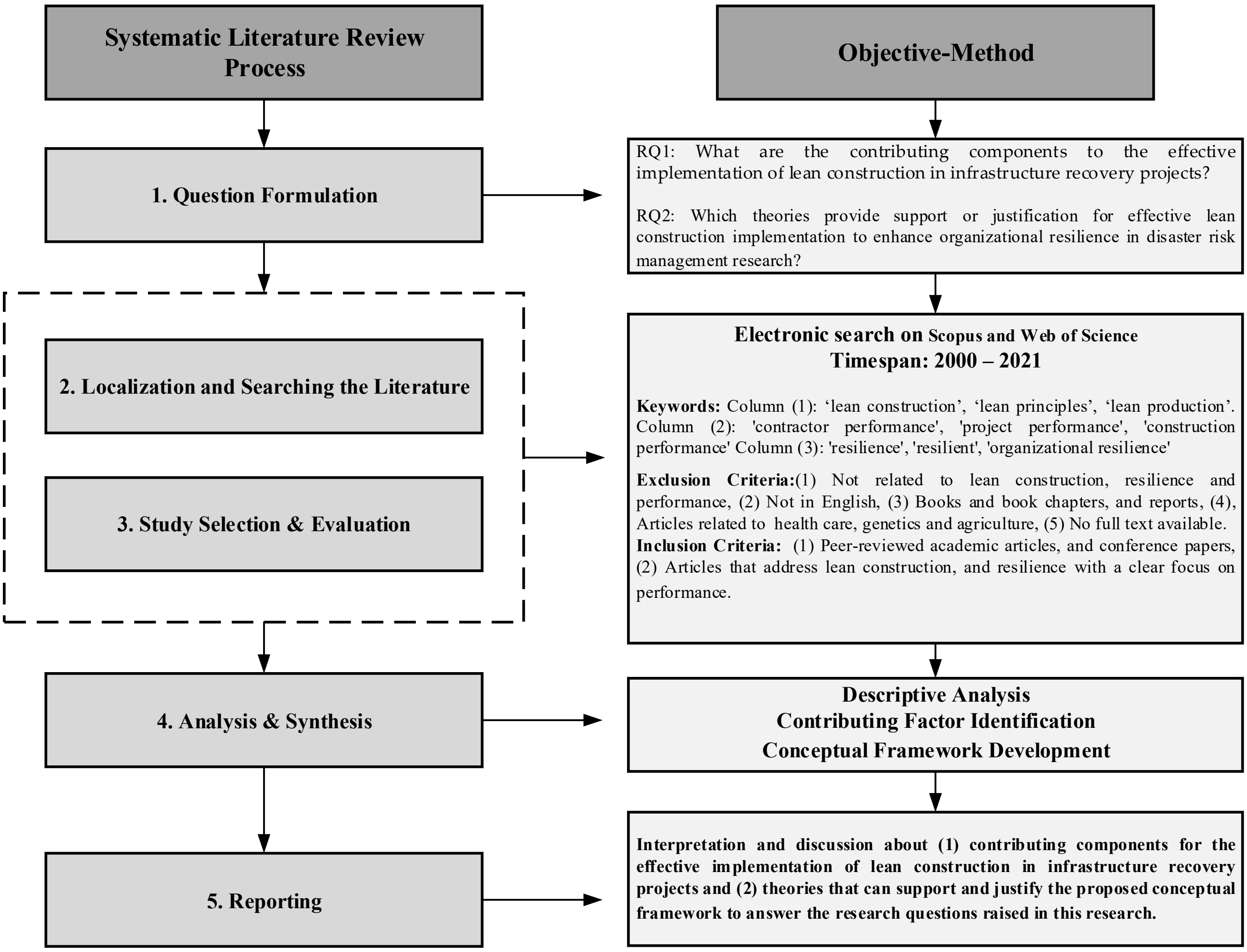

Figure 1. Summary of the systematic literature review.

Figure 2 contains the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [23] flow diagram for the current study. The identification step analyzed the titles, abstracts, and keywords of the 110 publications retrieved, and identified studies that were ineligible for the screening stage (37 papers). The following stage concentrated on filtering the 73 papers identified using the exclusion and inclusion criteria, respectively. The exclusion criteria concentrated on the general characteristics of the papers, such as their language and full-text availability, and resulted in the exclusion of 31 studies. The inclusion criteria were focused on the papers' scope, which emphasizes the triple concepts of lean construction, contractor performance, and organizational resilience. From the primary 110 documents identified in the databases, 73 were the subject of initial analysis and 18 were found to be appropriate for detailed analysis.

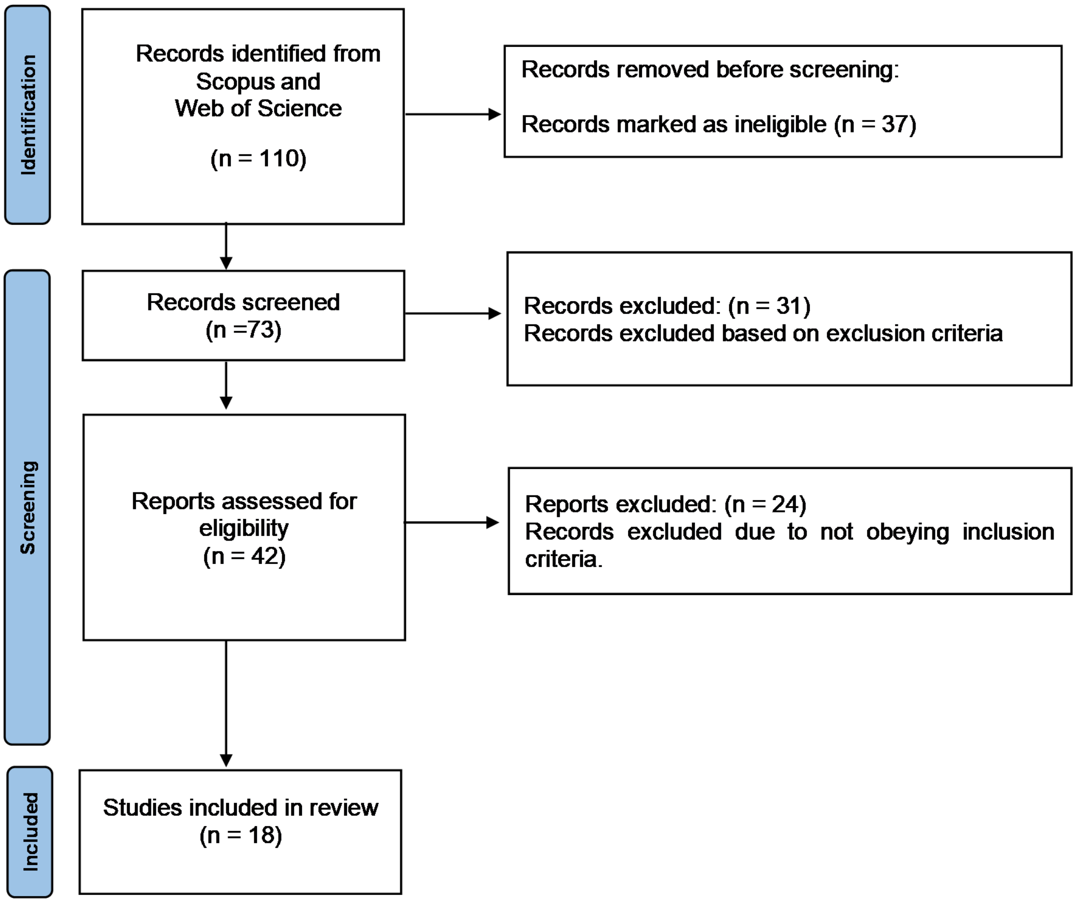

Figure 2. PRISMA results for current paper, format (adapted from Moher et al. [23]).

3. Results

Based on the PRISMA results, 18 papers meeting the defined SLR conditions were identified. This section describes these papers, first examining general trends, before focusing on the first research question: "What are the contributing components to the effective implementation of lean construction in infrastructure recovery projects?".

3.1. Descriptive Analysis of the Selected Studies

The descriptive analysis presents essential information associated with targeted studies and maps out the status of the publications in the research domain [15]. The findings of the descriptive analysis are listed in Table 1.

Table 1. The content analysis of the papers in the final stage of screening.

Author—References	Year	Country	Approach	Method	Contribution
Hundal et al. [24]	2021	United States	Qualitative	Interviews	Identifying Lean Six Sigma impact on organizational resilience
Nayak and Choudhary [25]	2021	India	Qualitative	Interviews	Conceptual development and empirical analysis
Touriki et al. [26]	2021	Morocco	Qualitative	Literature review	Exploring smart, green, resilient, and lean paradigms

Table 1. *Cont.*

Author—References	Year	Country	Approach	Method	Contribution
Trabucco and De Giovanni [27]	2021	Italy	Quantitative	Logistic regression models	Conceptual development and empirical analysis
Reyes et al. [28]	2021	Ecuador	Qualitative	Interviews	Conceptual development and empirical analysis
Habibi Rad et al. [11]	2021	Australia	Qualitative	Literature review	Development of a conceptual framework for integrating lean and resilience paradigms
Arumugam [14]	2020	India	Quantitative	Structural equation modelling	Conceptual development and empirical analysis
Das [29]	2019	United States	Quantitative	Case study	Integrating LARG paradigms in supply chain
Lotfi and Saghiri [30]	2018	United Kingdom	Quantitative	Structural equation modelling	Conceptual development and empirical analysis
Hadid et al. [31]	2018	United Kingdom	Theoretical	Structural equation modelling	Conceptual development and empirical analysis
Abushaikha et al. [32]	2018	Jordan	Mixed study	Structural equation modelling	Conceptual development through lean warehousing
Azadeh et al. [33]	2017	Iran	Quantitative	Adaptive neuro-fuzzy inference system (ANFIS)	Develop performance optimization approach
Jamali et al. [34]	2017	Iran	Quantitative	Case study	Analyzing LARG paradigms
Zarrin et al. [35]	2017	Iran	Quantitative	Data envelopment analysis	Simulation optimization of lean production
Azevedo et al. [36]	2016	Portugal	Quantitative	Case study	Develop a benchmarking tool
Birkie [37]	2016	Italy	Quantitative	Bayesian inference approach	Analyzing synergies and trade-offs between lean and operational resilience
Dubey et al. [38]	2016	India	Theoretical	Structural equation modelling	Conceptual development and empirical analysis
Figueira et al. [39]	2012	Portugal	Theoretical	Literature review	Development of a conceptual framework for safety design based on LARG paradigms

First, the papers were examined in terms of year of publication, which uncovered a growth trend from 2012 until 2021, with over 90% (17) of eligible papers being published after 2016. Significantly, no papers published prior to 2012 fulfilled the PRISMA criteria. Subsequently, the papers were classified by countries of origin: United States (2), United Kingdom (2), Portugal (2), Morocco (1), Jordan (1), Italy (2), Iran (3), India (3), Ecuador (1), and Australia (1). This geographic distribution suggests a global interest in developing the lean construction discipline.

Next, the research approaches applied in the papers were examined and classified into four categories. The dominant form of analysis identified is quantitative, with 50% (9) of all papers using this approach to conduct their research. The qualitative approach is in second place with 27% (5) of all papers. The theoretical development approach, with only 16% (3), is considered the third most prevalent in the targeted studies, while the mixed method, a combination of quantitative and qualitative, is used in only 7% (1) of studies. The methods applied in the selected studies were then analyzed to provide a comprehensive perspective of the studies. The most common method identified is structural equation modelling, applied in 28% (5) of all papers. In contrast, logistic regression modelling, adaptive neuro-fuzzy inference systems and data envelopment analysis are only used in 7% (1) of studies. Finally, the main contributions to the body of knowledge were examined. These findings highlight a potential need for further studies in the lean construction domain to improve their effectiveness in infrastructure recovery projects.

3.2. Contributing Components to Effective Implementation of Lean Construction in Infrastructure Recovery Projects

This section builds on the SLR to review the constructs and contributing components identified in the 18 PRISMA-compliant papers. It starts by reviewing key background principles for understanding the intersection of disaster recovery, organizational resilience and lean methodologies.

The literature identifies that post-disaster recovery of infrastructure projects is one of the most demanding tasks confronting construction professionals in disaster-affected regions. Following the 2004 Indian Ocean tsunami, resilience enhancement approaches ("build back better" principles) gained significant attention, leading to massive improvements in reconstruction phases of disaster risk management stages [40]. Past disaster experiences, such as the 2011 Christchurch earthquake and the 2016 Kaikoura earthquake, have further demonstrated that obtaining sufficient funding and high quality technical and physical assistance is a crucial issue for successful post-disaster recovery projects. The frequent failure of recovery projects can, in many cases, be ascribed to the contractor's poor performance or inadequate organizational resilience to cope with unexpected conditions [6,40]. The extreme conditions in infrastructure recovery projects, such as shortages of human resources and machinery, poor resource management, lack of sufficient funding, along with various risks, are responsible for degrading the effectiveness of recovery projects [3,6]. Therefore, implementing new managerial approaches has progressively become necessary to improve post-disaster infrastructure recovery projects.

The construction of infrastructure commonly involves complex and fragmented activities, demanding the inputs of various professionals, and resulting in challenging coordination requirements. Therefore, infrastructure projects of this type are faced with many obstacles, including the presence of non-value adding activities and processes [19]. One of the critical challenges which lead to performance issues in the recovery projects is a cost overrun, typically resulting from delays in meeting delivery timelines and material wastage [8]. In addition, reworks, which have been recognized as major causes of waste in construction, lead to both cost and time overruns [11]. Poor management procedures in recovery projects are another problem, causing extensive reworks in these developments and ultimately leading to cost and time overruns [7]. Thus, the research argues it is crucial to explore new processes, methods, and management practices that have the capacity to improve the performance of contractors.

One of the main approaches borrowed from the automotive manufacturing industry and applied in the construction sector is lean construction [41]. This approach has gained increasing popularity among practitioners and academics because it can minimize waste, maximize performance, and secure value for money to clients [19]. Despite the widespread application of lean construction approaches in conventional infrastructure projects, their implementation in disaster risk management phases such as reconstruction is still in its infancy. Thus, it is necessary to have a comprehensive overview of the disaster risk management stages and potential domains for implementing lean approaches in disaster recovery projects. Figure 3 illustrates the disaster risk management stages and operations required in the disaster life cycle timeline from pre-disaster to post-disaster. This study suggests implementing lean practices in the reconstruction stage and refers to this procedure as a Lean-Recovery practice to emphasize the importance of lean construction in a specific stage of disaster management.

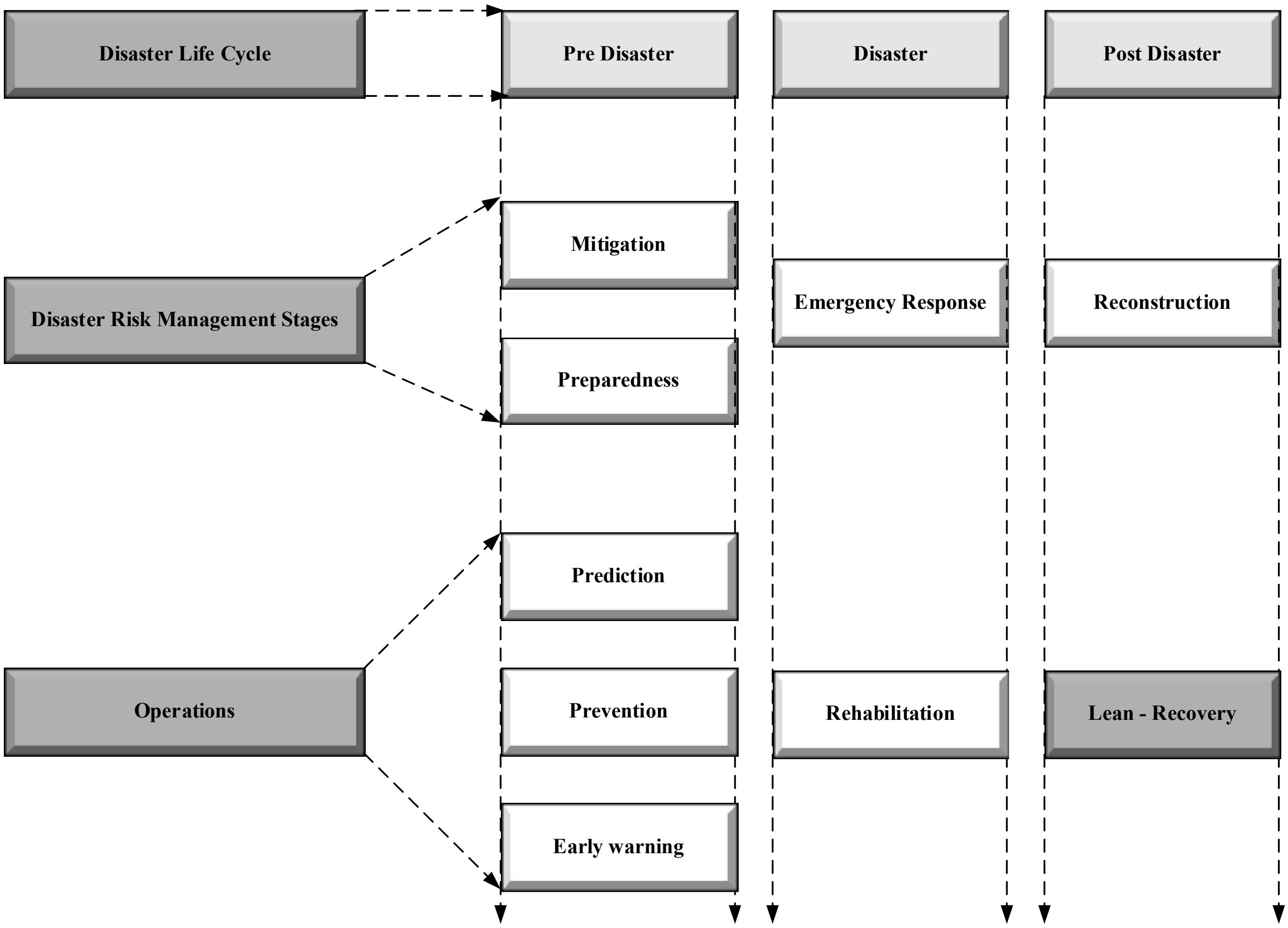

Figure 3. Lean-Recovery implementation in disaster risk management.

Although lean construction has attracted extensive attention from academics and practitioners, largely for addressing performance-related issues, few studies have investigated their impact on construction companies by focusing on organizational resilience [38,42]. On the specific topic of recovery projects, no research has been found. Hundal et al. [23] investigated the impact of lean six sigma on organizational resilience mechanisms and found that effective lean implementation is directly related to the applicability of appropriate lean tools and techniques in a particular area of request. However, shortcomings associated with recovery projects cannot be treated without considering efficient implementation mechanisms and organizational characteristics.

From this background, it is apparent that an important step forward is identifying contributing factors to implementing lean construction in infrastructure recovery projects. According to Dave et al. [43], there are specific characteristics that should be taken into account while implementing lean practices in infrastructure projects. These can be classified into three primary constructs—(i) lean construction, (ii) organizational resilience and (iii) contractor performance attributes—which are used in this paper to classify six contributing factors.

According to the SLR results, the first construct, lean construction, contains two main contributing factors: (i) lean tools and techniques, and (ii) lean principles [14,31,37]. Using appropriate lean tools and techniques that fit well with the objectives of projects can contribute to project success [18]. Moreover, finding alignments between lean principles and performance attributes associated with construction projects paves the way for the efficient adaptation of lean practices [44]. Koskela [45], for example, proposes eleven principles for lean construction that are grounded in the objectives of waste reduction, transparency, and continuous improvement. Howell and Ballard [46] claim that executing lean principle-driven procedures leads to a constructive shift in the management of companies and exposes new opportunities for continuous improvement in the developmental process. Nevertheless, successful implementation of lean principles necessitates that companies steadily and profoundly adjust the company's culture with respect to lean management perspectives [44]. It is noteworthy that implementing lean practices without providing sufficient cultural changes within an organization cannot accomplish a desirable outcome. Thus, considering the importance of organizational resilience, lean recovery must be executed effectively.

The second construct identified through SLR is organizational resilience. It is defined as the capability of organizations to survive and recover from emergencies and crises and succeed in uncertain environments [47]. Organizational resilience is a multidimensional concept including three main attributes: (i) leadership and culture; (ii) change readiness; and (iii) networks and relationships [48]. These attributes are key dimensions for providing adaptive capacity, effective communication engagement with internal and external stakeholders and crisis planning of organizations. The literature review acknowledges the role of organizational resilience in adopting new tools and techniques at the managerial level [14,49,50]. For instance, Hundal et al. [23] identify organizational resilience attributes that play a considerable role in the operational excellence of lean adaptation. Similarly, Da Costa Nogueira et al. [51] acknowledge the role of organizational resilience, especially leadership, in lean implementation success.

The third construct identified through SLR is contractor performance. It comprises the performance indicators that require to be improved through lean implementation. Lotfi and Saghiri [29] empirically scrutinized how operational performance outcomes can improve resilience. Their findings indicate that each indicator's level of improvements, such as cost and time, varies under different disruption scenarios. Consequently, a comprehensive performance construct covering a wide range of indices is becoming imperative to assess the effectiveness of lean implementation in recovery projects.

Table 2 presents constructs and contributing components that significantly contribute to the effective implementation of lean construction in infrastructure recovery projects. These components are classified into six groups based on their ascribed construct to provide a comprehensive understanding of factors that can influence the effectiveness of lean implementation. A detailed description of each component is provided to support the use of lean construction in infrastructure recovery projects.

3.3. Overview of Theories

A substantial number of theories are used to understand or conceptualize lean construction in the literature, several of which are identified in the SLR [11,30,31]. Koskela [62], for example, proposed the Transformation-Flow-Value generation (TFV) theory of production as a foundation for understanding and developing lean practices in construction projects. The TFV theory has been used to explore both explanatory and descriptive research [63]. It is grounded on three interdependent production components: (i) transformation (laborer and machinery oriented), (ii) flow (materials oriented) and (iii) value (customer-oriented) [45]. The TFV theory has served as a fundamental pillar for addressing deficiencies in construction research within three major domains: (1) chronic performance-related problems, (2) in the absence of explicit theory to integrate flow and value management and (3) developing industrialization or information-based technologies in construction [62]. TFV theory, by superimposing characteristics originating from the flow and value generation onto the transformation, strives to reduce the adverse impact of variability on construction tasks [64].

Table 2. Contributing components to effective implementation of lean construction in infrastructure recovery projects.

Construct	Contributing Component	Description	References
Lean Construction	Tools and Techniques	Selecting appropriate lean tools and techniques is crucial to achieving infrastructure recovery project goals. This way, most of the benefits associated with each tool can be gained. A list of lean tools contains Just-in-time, Total quality management, the Last Planner System, Prefabrication and modularization, Visual Management, Six Sigma, etc.	[19,41,52]
	Principles	A comprehensive understanding of the compatibility of lean construction principles in infrastructure recovery projects could define the extent of alignment and synergy between these principles and contractor performance attributes, which results in a higher outcome.	[12,53,54]
Contractor Performance	Performance Indicators	Providing a comprehensive Contractors' Performance construct that covers sets of Key Performance Indicators (KPIs) contributes to the effectiveness of lean implementation in recovery projects.	[55–59]
Organizational Resilience	Leadership and Culture	The leadership and culture shape the adaptive capacity of the organization. Five main attributes cover this construct: leadership, decision-making, staff engagement, innovation and creativity, and situation awareness.	[42,49,60]
	Change Readiness	Change readiness must be considered by providing proactive planning to make organizations ready against the crisis. Four significant attributes cover this construct: unity of purpose, stress testing plans, proactive posture, and planning strategies.	[60,61]
	Networks and Relationships	The network and relationship construct is responsible for effective engagement of internal and external relationships among diverse stakeholders. It includes four main attributes: effective partnership, breaking silos, and leveraging knowledge and internal resources.	[47,48,60]

Recent literature recognizes the role of lean practices in improving performance in conventional construction projects [13,31,32]. Abushaikha et al. [32], for example, argue that lean implementation in warehouses positively enhances the overall operational performance. Likewise, Gambatese et al. [44] investigated the role of lean practices on safety behavior through a survey of industry practitioners. The results support the perspective that implementation of lean practice is most beneficial to safety performance. On the other hand, Pearce [65] argues that the success of lean implementation in many industries is tainted due to the lack of applicability of lean practices beyond mass production projects. This lack of consensus among academics and experts about the applicability of lean tools in various project types raises an urgent need for further research. To address this issue, empirical research could play a significant role by providing tangible statistical evidence to educate practitioners. Contingency theory is one of the main theories used in empirical research conducted to examine the impact of lean practices on different performance criteria.

Organizational performance has always been a controversial issue within construction management research. The increasing attempt to discover reasons behind the outperform of some organizations over others has acted as a catalyst to find innovative performance improvement approaches. Eventually, a continuous improvement concept was proposed within the construction industry, which involved minimizing waste and maximizing value by adopting different lean construction practices [12,41]. The notion of contingency theory is borrowed in lean studies to explain the indispensable role of lean practices in performance enhancement. The contingency concept can be viewed as an extension of the systematic approach that underlines the potential to differentiate among alternative forms of organizational structures [66]. Kreitner et al. [67] argue that the contingency approach attempts to discover which managerial practices and techniques are applicable in certain conditions. Donaldson [68] asserts that there is no single best way to manage a project in every situation due to the unique nature of projects. It is accepted that any given technique's achievement is relative to real-life applications. Contingency theory focuses on finding the best way to manage an organization by emphasizing the significance of environmental circumstances on the management of organizations. The contingency perspective contradicts the traditional universal approach of 'one best way'. It suggests that organizational performance can be gained in multiple ways. These ways are predominantly affected by the dynamic relationships between an organization and its operational environment [69]. Donaldson [68] notes that different contingency factors affect organizational performance, and recommends that the organization's management should seek the best-fit between its internal and external environmental circumstances. Regarding lean studies, this approach asserts that best practice is contingent upon the circumstances and projected outcomes of each unique organization.

Construction organizations in the post-disaster environment face numerous risks that threaten operational performance and stability. Hamel [70] contends that the circumstances around organizations tend to shift to turbulence quicker than they are resilient to change. These increasingly volatile external and internal factors impose tremendous pressure on the organizational resilience of construction companies, including their capacity to survive and sustain under these conditions. In the context of organizational theory, resilience commonly has been used to point to a characteristic or capacity of individuals or organizations, or more specifically, the ability to absorb pressure and maintain or increase functioning, despite the presence of adversity [48].

In addition to the two main theories identified through the SLR (TFV and Contingency), several others are referred to in the secondary literature. For example, multiple studies have been conducted in order to implement lean practices at the organizational level [14,42,49]. These studies have focused on various dimensions of organizational resilience. For instance, Da Costa Nogueira [51] examined the relationship between leadership and lean management. Moreover, Hadid et al. [31] conducted a study about the socio-technical perspective of lean, which could be classified in studies pertinent to networks and relationships characteristics of organizations. Abushaikha et al. [32] scrutinized the improvement of business performance through lean implementation of distribution in the warehousing context, which is considered an approach to enhancing change readiness of organizations under disruptive events. A few theories regarding the socio-technical systems view have been used to develop organizational resilience. High-reliability organization (HRO) and normal accident theories are among the most important theories used to justify exploratory research in this emerging domain [47]. The implications of HRO theory have grown and spread in organizational resilience research by enhancing operational reliability within organizations [71]. Academics have also shown great interest in HRO as a reliability seeking approach in organizational research. In contrast, disaster research has extensively used normal accident theory to address subjects pertinent to systemic awareness in disruptive environments and the trade-off between increased systemic risk and efficiency [72].

Disaster and crisis theories have been systematically reviewed and classified by Sementelli [73]. This classification is based on processes and tools implemented in the disaster research and classified into four groups: (i) economic theories, (ii) social theories, (iii) administrative theories and (iv) decision theories. The classification of these theories could assist in finding synergies and discrepancies in the integration of various theories for the justification of complex conceptual frameworks. Economic theories cover a wide range of perspectives, from short-term tactical strategies to long-term rehabilitation strategies focusing on a disaster's impact on economic factors. Transaction cost economics is a highly capable theory that fits well with studies focused on the delivery of services and products [74]. Humanitarian supply chain and post-disaster recovery projects are only a few examples of potential areas that could apply the theory of transaction cost economics. Another theory that could play a significant role in recovery projects from an economic perspective is resource dependence theory. It aims to explain how organizations reduce environmental interdependence and uncertainty [75]. On the other hand, social theories attempt to address disaster challenges by process-oriented activities. The majority of the secondary literature identified through the process of developing this SLR is focused on the contextualization of disaster and crisis theories from a social policy standpoint. Moreover, the administrative group of theories is focused on management theories and leadership theories. Institutional theory [76] and stakeholder theory [77] are among the most preferred theories used in the administrative group. These theories have a focus on processes as well as the implementation of new tools within an organization [73]. Finally, decision theories focus on executing approaches through the application of new tools in disaster science. These mainly contribute to achieving specific practical purposes and often have less concern for the processes employed to reach these objectives.

4. Conceptual Framework

Two research questions are raised in this paper. The first asks about the components that contribute to the effective implementation of lean construction in infrastructure recovery projects. This question is answered through an SLR and diverse content analysis in Section 3.2. Specifically, six contributing components are identified. The second question asks about theories supporting and justifying the concept of effective lean construction implementation to enhance organizational resilience in disaster risk management research. Section 3.3. examines the contributions of various theories in different contexts to answer the second question.

This section proposes a conceptual framework for the operationalization of contributing factors to implement lean construction in infrastructure recovery projects effectively. To provide a robust, theoretical justification for the proposed conceptual framework, a series of hypotheses are presented. Finally, contributions to the body of knowledge, research limitations and suggestions for further studies are proposed.

4.1. Developing the Conceptual Framework

Drawing upon the findings of this SLR and the answers to the two research questions, a theoretical framework is proposed. Three primary constructs are required to justify the development of a theoretical framework for implementing lean recovery in infrastructure projects. These constructs are (i) lean construction, (ii) contractor performance and (iii) organizational resilience of construction companies (Section 3.2).

First, the lean construction construct was proposed to represent two contributing components: (1) tools and techniques and (2) principles. This construct provides a comprehensive overview of appropriate tools, techniques, and viable principles for infrastructure recovery projects. Babalola et al. [19] conducted a systematic literature review to identify and categorize the various lean tools and techniques executed in multiple stages of construction projects, from design and engineering, planning and control, to construction and site management. In addition, Tezel et al. [41] examined the implementation of lean construction practices within transportation infrastructure. Their findings revealed significant motivators for construction contractors to adopt lean technologies, including companies' expectations of winning more contracts as well as the operational benefits of lean practices. Therefore, making appropriate decisions about the tools used to meet the expectations of infrastructure recovery projects is of great importance to maximizing the value for clients.

Conversely, applying lean construction principles has caused heated debate among academics. For instance, Randolph et al. [78] argued that implementing these principles could reduce variability in construction projects and ultimately lead to performance improvement. Likewise, Gambatese et al. [44] examined synergies between these principles and safety performance attributes. Their results support the standpoint that many similarities exist between the application and impacts of lean principles and safety performance aspects. Consequently, providing a comprehensive construct that includes both tools and principles associated with lean is necessary to develop a conceptual foundation for the effective implementation of lean construction in infrastructure recovery projects.

Second, the framework accepts Aziz et al.'s [12] proposition that applying lean thinking approaches in construction projects improves performance. Evidence suggests that implementing lean techniques has helped organizations improve their operational performance [79,80]. However, the real impact of these tools on contractor performance, such as cost, quality, time, and safety, is still unclear. Meanwhile, different academics have tried to investigate the effect of these lean practices on specific individual measures [44] and overlooked the investigation of lean influences on overall and combined contractor performance indicators. Therefore, the contractor performance construct is developed for addressing these issues and providing a comprehensive standpoint for the overall impacts of lean practices on performance measures. Finally, the organizational resilience construct is integrated into the framework to develop construction companies' strengths and weaknesses before a disaster occurs and increase their readiness for effective implementation of lean practices to achieve a higher level of performance. Figure 4 illustrates a theoretical framework for implementing lean construction tools and techniques in infrastructure recovery projects. Notably, the relationships between the three involve several assumed dependencies, which the following section recasts as hypotheses.

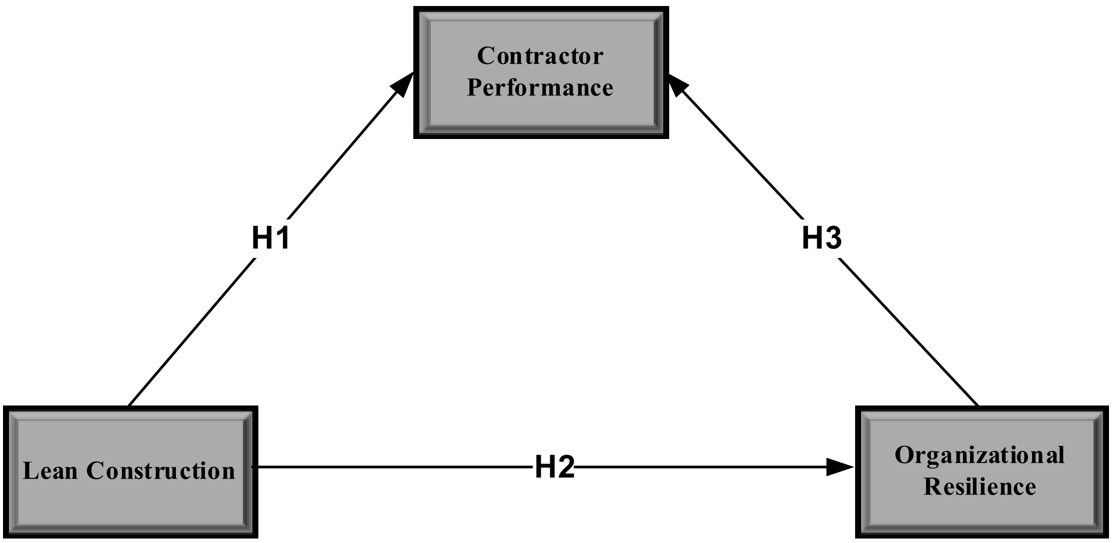

Figure 4. Theoretical framework for operationalization of contributing factors to effectively implement lean construction in infrastructure recovery projects.

4.2. Hypotheses Underpinning the Conceptual Framework

Implementing lean practices in infrastructure recovery projects, as proposed in the new theoretical framework (Figure 4), requires an understanding of the interrelationship among lean construction practices, contractor performance indicators and organizational resilience attributes. The objective of this sub-section is to formulate relevant hypotheses to address these interrelationships. This study proposes three hypotheses that need to be developed concerning how these constructs impact each other. The purpose of this formulation is to provide logical support for the framework by defining: (i) the ways implementation of lean recovery affects organizational resilience and contractor performance and (ii) the lean practices that are more efficient.

The research questions posed in the current study pave the way for supporting the developed hypotheses through two constructive approaches. By investigating the contributing components to implementing lean construction, the first question makes a significant contribution by developing three constructs of the proposed theoretical framework (Figure 4). On the other hand, the second question, by analyzing theories that support the proposed conceptual framework, can assist in the justification of proposed hypotheses. Thus, these two questions play a complementary role in developing a conceptual framework.

This study proposes three hypotheses, each derived from the results of the SLR and evidence about the ways these constructs impact each other [81,82]. The hypotheses are grounded in the developed conceptual framework, and each clarifies how one construct affects another. Figure 4 depicts the hypotheses (H1, H2, and H3).

H1 proposes that lean construction implementation has a supportive impact on contractor performance. The increasing importance of performance throughout the infrastructure recovery process has forced contractors to apply new tools and techniques to improve their performance. Although lean construction practices have been utilized extensively in conventional construction projects [12,52], to date, there is no consensus about their impact on recovery projects. Thus, a hypothesis is required which addresses this issue.

Hypothesis (H1). *The implementation of lean construction in a contractor improves performance.*

H2 proposes that lean construction implementation has a supportive impact on organizational resilience. An understanding of how lean practices impact organizational resilience is important to identify new approaches for the adaptation of lean to deal with the weaknesses and strengths aspect of organizations. Thus, we proposed the following hypothesis:

Hypothesis (H2). *The implementation of lean construction in a contractor's organization improves organizational resilience.*

H3 maintains that organizational resilience enhancement has a supportive impact on contractor performance. Many researchers have developed evidence that improving organizational attributes such as leadership [50] and culture [83] positively impacts organizational performance. However, an understanding of this issue in recovery projects is still missing. Thus, we proposed the following hypothesis:

Hypothesis (H3). *Increased organizational resilience improves contractor performance.*

These hypotheses are neither tested nor validated in the current paper, and although they reflect the evidence and arguments uncovered by the SLR, they still need to be critically examined in future research. The significance of the proposed hypotheses in this paper is to develop a conceptual framework that provides a foundation for the effective implementation of lean construction in infrastructure recovery projects.

Although several of the theories identified in the previous section provide a level of justification for the proposed conceptual framework and hypotheses, TFV and contingency theories provide the strongest foundation. First, infrastructure recovery projects have ever-changing environments, exposing them to multiple contingency factors and affecting organizational performance. Thus, improving their performance through the best-fit approach based on different scenarios is a must for companies' survival in a competitive recovery environment. Second, to achieve improved contractor performance, three concepts derived from TFV theory are significant: "transformation should be efficient", "flow should be reliable", and "value of work relies on the effective completion of the preceding work" [53,54,84]. Thus, TFV theory, by optimizing transformation, facilitating flow, and maximizing value, supports the proposed conceptual framework.

5. Discussion

5.1. Contribution to the Body of Knowledge in Disaster Risk Management

The current study investigates the contributing components to developing a conceptual framework for the effective implementation of lean construction in infrastructure recovery projects and provides theories that can support and justify the proposed framework through a systematic literature review.

This study contributes to the body of knowledge on organizational resilience and lean thinking studies in many ways. First, this study has proposed a conceptual framework to implement lean practices in infrastructure recovery projects. Second, contributing components to implementing lean tools at the organizational level are identified. Third, it has explored the theories that could be used to integrate lean and resilience paradigms within a disaster research context.

These outcomes provide scholars with a way of employing these components and theories in their future studies to improve the implementation of lean recovery in a disaster reconstruction context. By adopting these approaches, disaster management professionals could be better prepared to support their organizations' resilience. In parallel, the current study is expected to assist practitioners in overcoming challenges in the lean construction implementation process and guide them through the processes of considering and prioritizing tasks concerning performance-based issues when implementing lean in their organizations. As a result, the conceptual framework developed in this study aims to support top and middle management in construction companies to achieve better results by implementing lean practices.

5.2. Research Limitations and Future Research Paths

There are several limitations in the proposed theoretical framework, which suggest the need for future studies. First, it is recognized that the nature of infrastructure recovery projects varies over time, and different priorities concerning project success can lead to varied results. Second, external environmental factors could pose different threats to the organizational resilience of construction companies and ultimately can lead to the reduction in performance of recovery projects. As a result, further research on the impact of external environmental factors, such as the social and economic environment, on the proposed framework may provide evidence for convincing recovery practitioners to shift away from conventional approaches to lean recovery ones.

Although this research has been organized systematically, there are methodological limitations to the SLR. First, the data were collected from peer-reviewed academic journals and conferences, which excluded doctoral and master's theses and textbooks. The second constraint was the gathering of papers from English-language journals only. Consequently, the systematic review did not cover journals in other languages.

While the current study attempts to integrate diverse theories into the conceptual framework, this paper does not attempt to empirically validate the proposed framework. The exploratory analysis of the conceptual framework using advanced statistical analysis, such as structural equation modelling (SEM), is proposed as a future research direction. Moreover, this study only investigates the implications of lean practices for the recovery stage of disaster risk management and accepts that lean construction practices can also potentially improve infrastructure projects in parallel with contractor performance. Further research is required to investigate the impact of lean tools on the response stage of disaster risk management in order to scrutinize lean practices applicability in various stages of disaster risk management. Finally, the study's findings on the relationships between lean construction, contractor performance, and organizational resilience have the potential to provide a more profound understanding of the relationships between lean implementation and organizational characteristics in future studies.

6. Conclusions

The primary purpose of the current research is to propose a conceptual framework to improve contractor performance and organizational resilience through lean construction implementation. To do this, this paper reports on the results of an SLR examining the effective implementation of lean construction tools on infrastructure recovery projects. In the SLR, an initial set of 110 papers was detected, which was reduced to a final collection of 18 papers published between 2012 to December 2021. The SLR process was chosen to examine a substantial sample of papers within the research context to improve the reliability of outcomes. This study was applied to respond to two research questions. The first asks: what are the contributing components to the effective implementation of lean construction in infrastructure recovery projects? Section 3.2 and Table 2 list the six contributing components. The second research question asks: which theories provide support or justification for effective lean construction implementation to enhance organizational resilience in disaster risk management research? The answer, which is presented in Section 3.3, is developed by synthesizing theories that then provide the foundation for the theoretical framework.

This paper presents three contributions. First, it adopts an integrated theoretical approach, incorporating TFV and contingency theories. Second, it advocates for the need to consider economic and administrative theories to integrate lean and resilience paradigms within recovery projects. Third, it proposes the operationalization of lean principles under multidimensional disturbances to improve contractor performance and organizational resilience in infrastructure recovery projects. In this regard, the proposed conceptual framework could serve as a road map for construction companies to improve their performance and organizational resilience, while mitigating risks associated with implementing lean practices in their infrastructure projects.

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