buildings

MDPI

Systematic Review

A Systematic Review of the Evolution of the Concept of Resilience in the Construction Industry

Jinjing Li, Haizhe Yu and Xiaopeng Deng *

China-Pakistan Belt and Road Joint Laboratory on Smart Disaster Prevention of Major Infrastructures, Southeast University, Nanjing 211189, China; li_jinjing2@163.com (J.L.); 230238347@seu.edu.cn (H.Y.)
* Correspondence: dxp@seu.edu.cn

Abstract: Despite the growing importance of resilience in the construction sector, the existing literature often focuses on specific systems or functions without integrating a holistic view of resilience. Hence, there is a pressing need for comprehensive research that synthesizes these dimensions to provide a clearer framework for resilience in the construction industry. To find the inherent patterns and trends of resilience, we carried out research from the perspective of three elements defining resilience (the subject of resilience, the influencing factors, and the subject's ability). In this systematic review, 70 articles were rigorously handpicked from Web of Science, Scopus, and authoritative journals and divided into 6 major categories and 24 subcategories for quantitative and temporal analyses. The evolution of resilience in the construction industry is investigated in this review, shifting from specific systems facing defined impacts to addressing the complexities of diverse and unpredictable disruptions within VUCA (volatile, uncertain, complex, and ambiguous) environments. As Industry 4.0 and digital transformation progress, the significance of functional resilience across various system levels becomes apparent, necessitating a reconstitution into structural, operational, and supply chain resilience. This study encourages the use of advanced methodologies like big data, AI, and high-level architecture (HLA) federated simulations to predict disruptions and optimize resilience strategies, thus providing a robust foundation for handling future uncertainties.

Keywords: resilience strategies; construction industry; uncertainty; safety management; risk management; resilience evolution

Citation: Li, J.; Yu, H.; Deng, X. A Systematic Review of the Evolution of the Concept of Resilience in the Construction Industry. *Buildings* **2024**, *14*, 2643. https://doi.org/10.3390/buildings14092643

Academic Editor: Ahmed Senouci

Received: 23 July 2024
Revised: 24 August 2024
Accepted: 25 August 2024
Published: 26 August 2024

1. Introduction

The landscape of the construction industry has changed dramatically in these early years of the post-COVID-19 era, characterized by increasing volatility, uncertainty, complexity, and ambiguity (VUCA) [1]. As a result of this shift, those involved in the construction industry need to acquire a broader and more adaptive understanding of resilience [2]. The diversity of environments and unpredictable disruptions have made resilience research in the construction industry more complex and challenging. However, at the same time, the significance of resilience research is growing as this industry seeks effective strategies for coping with these challenges.

Previous studies have explored resilience in the construction industry from various angles. For instance, the authors of some articles have tried to sort out the knowledge framework involved from the perspective of the safety and resilience of workers participating in construction projects [3]. Some articles have examined the factors contributing to resilience in safety management [4]. Additionally, studies have investigated the causes and influences of safety resilience in construction projects or construction teams [5]. Although each article has a different perspective on resilience in the construction industry, there is a general consensus on the definition of resilience across all studies: resilience is the ability to help a system anticipate, defend against, and recover from abnormal injuries to allow it to continue to achieve its objectives [6]. However, the existing reviews often concentrate on specific systems or functions without addressing the overarching concept of resilience. Given the pressing need to develop the concept of resilience in response to the VUCA environment, a review focusing on the concept of resilience itself and an exploration of its development and future trends is necessary.

The concept of resilience was first introduced in the 1970s [7]. Resilience is a measure of a system's ability to continue to perform despite impacts [8]. This definition can be divided into three different dimensions depending on the term: the subject of the resilience, the capacity of the subject, and the impact. Therefore, to reveal how resilience has developed and evolved, the development and evolution of these three dimensions should be studied. Resilience refers to any subject in a study that can show resilience after an impact. The scope of the subject considered varies according to the scope of the study. The subjects of resilience in previous reviews were defined in a wide range of ways, including organizations [9], supply chains [10], companies [11], transportation systems [12], urban infrastructure networks [13], and mental health [14]. The impact of uncertainty refers to a change that the subject of resilience passively suffers. This change might stem from a physical natural disaster [15] or an abstract shock [14]. The capacity of the subject is then reflected in the nature of the subject itself. This aspect specifically refers to the subject's ability to maintain or recover its shock-type capacity in order to act on other things. No review article has examined all three perspectives, although previous studies have included all three dimensions. In addition, theoretically, the resilience of all systems should be interconnected, but the definitions in existing articles leave the connection of different types of resilience unclear. Hence, analyzing the evolution of the concept of resilience from these three perspectives is necessary for clear and rational resilience development.

Given the above research gaps, this paper will start by posing the following research questions: How has the concept of resilience evolved in the construction industry in response to the VUCA environment? What emerging trends and strategies can be identified to enhance resilience in the construction sector amidst increasing uncertainty and complexity? In addition, two hypotheses are developed to address these two questions: H0— There has been no significant change in the three dimensions of the resilience concept within the construction industry over the past decade, and H1—There has been a significant change in the three dimensions of the resilience concept within the construction industry over the past decade.

Based on three perspectives on the definition of resilience mentioned above, namely, the subject of resilience, the impact of uncertainty, and the service that the subject recovers from, this systematic review aims to find out the evolution of resilience within the construction industry, tracing its journey from a static concept focused on isolated incidents to a dynamic, holistic approach. By examining the emerging trends, challenges, and strategies, in this paper, we seek to provide a comprehensive understanding of how the construction sector can enhance its resilience in today's VUCA world. Through this exploration, this study will shed light on the key factors that contribute to a resilient construction industry capable of thriving amidst uncertainty and complexity. In addition, through a comprehensive assessment of resilient subjects, uncertain impacts, and the roles created by the subjects, we aim to provide the construction industry with valuable references and guidance in the face of increasingly complex and unpredictable environments, building strong bases for its sustainable performance.

In the next part of this paper, the following will be presented (in order): the Section 2 will present the detailed and specific literature search process carried out and the screening results obtained; the Section 3 will present the quantitative and temporal analyses conducted according to the three dimensions of the concept of resilience; the Section 4 will present the results of the analyses based on the research questions and indicate the trends of future research; and the Section 5 will summarize this work and point out the possible research limitations.

2. Methodology

To provide the rigorous and standardized analysis of the research areas covered in this study, this review follows the PRISMA principles [16] for systematic review studies. The PRISMA guidelines enhance the consistency, transparency, and credibility of systematic reviews by providing a standardized framework that ensures thorough literature coverage and facilitates the reproducibility and updating of reviews. We used a research framework similar to the frameworks used in other studies [17]. The three dimensions of the definition of resilience were searched, and information was extracted from the literature and categorized in detail, providing an intrinsic understanding of the current state of development and trends. Hence, the review methodology framework consists of a search strategy, selection, extraction, and assessment, as described below.

2.1. Search Strategy

The databases searched were Scopus and Web of Science, which offer extensive and interdisciplinary coverage of the scholarly literature, ensuring a comprehensive retrieval of high-quality, peer-reviewed materials across various fields. These databases provide sophisticated search tools, citation tracking, and access to a wide range of materials, including grey literature, which enhances the thoroughness and reliability of the literature review process. Also, Scopus and Web of Science are designed to facilitate broad, deep searches, making them indispensable tools in many academic and scientific fields [18].

Spanning from the earliest research published in 2004, this review sample covers 20 years: 2004 to 2024. To maintain the diversity of a sample, the type of articles selected should include both conference papers and journal articles. In this case, review articles were excluded because they might not have contained information on the three dimensions under examination.

Since this review examines the overall situation regarding “resilience” in the “construction industry”, it was critical to ensure that there were not too many search terms around the two keywords that would influence the scope and results of this study. Therefore, the original search terms summarized from other journals [19] were “construction industry” or “civil engineering” or “construction engineering” or “architecture engineering” or “construction sector” or “building industry” or “construction project” and “resilience” OR “adaptive capacity” OR “robustness” OR “recoverability” OR “durability”. Table 1 shows the advanced search syntax corresponding to the different database applications. Only English articles were included, while those written in other languages and other types of papers were excluded during primary screening.

Table 1. Search strategy used for different databases.

Database	Search Strings	Number
Scopus	(TITLE-ABS-KEY(“construction industry” OR “civil engineering” OR “construction engineering” OR “architecture engineering” OR “construction sector” OR “building industry” OR “construction project”) AND TITLE-ABS-KEY(“resilience” OR “adaptive capacity” OR “robustness” OR “recoverability” OR “durability”) AND TITLE (“resilience” OR “resilient”))	451
Web of Science	(TS = (“construction industry” OR “civil engineering” OR “construction engineering” OR “architecture engineering” OR “construction sector” OR “building industry” OR “construction project”) AND TS = (“resilience” OR “adaptive capacity” OR “robustness” OR “recoverability” OR “durability”) AND TI = (“resilience” OR “resilient”))	763

In total, 451 relevant articles were retrieved from Web of Science, and 763 were taken from Scopus. A total of 792 articles remained after eliminating duplicates.

2.2. Selection

The selection process was divided into three parts: the creation of the selection criteria, initial screening, and eligibility assessment.

Selection criteria are established based on how the analyzed studies are evaluated and then selected for inclusion in the corresponding review. Based on this principle, the research topics of the reviewed articles should be in line with resilience and the construction industry. The research in this article was conducted from the perspective of the definition of resilience. Therefore, the studies in the selected articles should include the four elements that this review focuses on: the subject of resilience, the cause of resilience, the purpose of the subject's role, and the role played by the subject. The type of resilience discussed in this systematic review belongs to the category of management, and all information on physical resilience referring to mechanical structures was excluded. In addition, all the articles examined needed to contain an exact research design. Studies with ambiguous findings and no positive results were discarded.

In the initial phase of screening in Figure 1, we skimmed the titles and abstracts of the articles to quickly identify whether they met the inclusion criteria. In this process, 332 articles were initially included, and 460 were excluded. The selected articles were then subjected to an eligibility assessment, and each article was read in detail in its entirety. Selection principles other than fitness for purpose were applied to select experimental articles that aligned with the purpose of this systematic study. In total, 68 high-quality articles were selected. In addition, two articles were added from the excellent journals Automation in Construction and Buildings. Both are excellent articles that were retrieved from these journals' websites by entering keywords related to resilience and the construction industry that were not included in the database search. Finally, a total of 70 research articles that fit the purpose of this study were found.

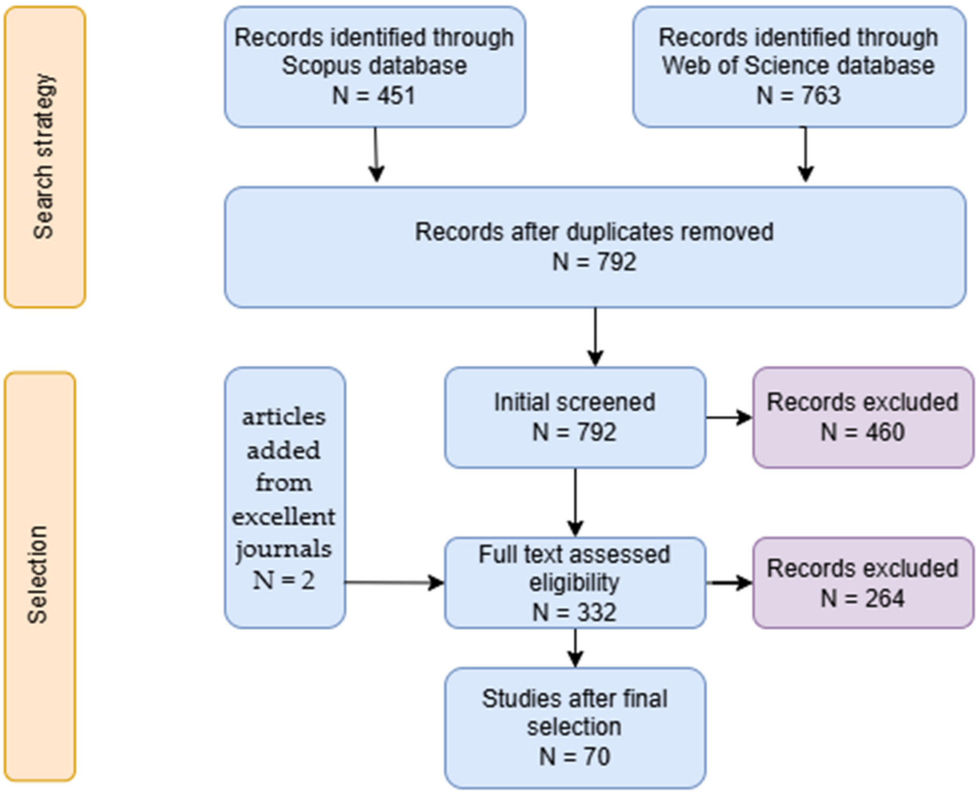

Figure 1. The PRISMA framework for the selection process.

2.3. Extraction

The processing software used for information collection was Excel 2024 (Microsoft, Redmond, WA, USA). As a common tool for processing complex data, Python was employed to illustrate the degree of relationship between nodes.

The data that met the aims of this experiment were extracted, including the following variables: title, time, subject of resilience, cause of resilience, subject of object, and the effect of the subject's resilience on the object.

2.4. Assessment

Since there is potential for oversight and errors in subjective human reviews, an inter-assessment procedure should be conducted after the information has been collected. In this session, each dimension of data is re-examined in detail by a different team member until the results are the same on both sides of the review. Data that are not the same during the checking process are submitted to the remaining staff for judgment. Data that do not meet the requirements are deleted. All data in this assessment met the requirements.

3. Results

To examine the questions and hypotheses claimed above, in this section, we analyze the data obtained and present the results objectively from the perspective of the three components of the definition of resilience: the subject of resilience, the impact factors, and the role of the subject. We found that H1 (there have been great changes in the three perspectives of the resilience concept in the construction industry) is correct. The following sections will introduce the changes and trends over time.

3.1. The Subject of Resilience

As the subject of resilience is also an agent of uncertainty, its research composition is complex and varied. After their selection, 70 articles were divided into two categories, namely, a specific class and a general class, after aggregation based on whether they involve definite entities, locations, or detailed projects. The main differences between the specific and general classes are specificity versus abstraction, the object of study versus the focus, and volume versus trend. The specific category emphasizes specific projects and implementation details, while the general category focuses on broader theoretical and societal implications.

As shown in Table 2, the number corresponding to each subcategory represents the number of articles with which it is associated. In the "Specific Class", there are 18 entries that focus on tangible, concrete elements such as specific construction projects, definite facilities and systems, explicit geographic locations, and particular infrastructure systems. The "General Class" consists of 52 entries that encompass broader concepts or abstract themes not directly referring to specific entities or detailed locales.

Table 2. A categorized summary table of resilient subjects.

Main Categories	Subcategories	Number of Samples	Total
Specific Class	Specific Construction Projects	3	18
	Concrete Facilities and Systems	4	
	Definite Geographic Locations	4	
	Specific Infrastructure Systems	7	
General Class	Industries and Fields	18	52
	Concepts and Methods	4	
	Extensive Networks and Systems	19	
	Social and Community Impact	11	

3.1.1. Specific Class

The specific construction projects examined include clearly defined projects like innovative building projects [20], construction sector SMEs and their supply chains [21], and construction refurbishment projects [22]. The requirement for inclusion in this entry is that the subject of the study involves a specific building project rather than a generalized entire project. Furthermore, this class encapsulates certain infrastructure elements such as highway bridges and bridge networks [23–26] and seaport and infrastructure systems [27–29]. These topics are typically concerned with precise implementation details and physical locations, representing the more quantifiable and definitive aspects of research.

Some subjects of study, however, are not abstract engineering projects or engineering systems but rather concrete facilities or urban building bodies. The distinct facilities include petrochemical plants [30], buildings [31,32], and acute care facilities [33]. Geographic specifics are also covered, featuring locales like Khartoum [34], Shenyang City [35], Spain [36], and San Francisco [37].

3.1.2. General Class

This class includes categories like industries and fields, with examples including the construction industry [38], construction projects [39–48], construction organizations [49–54], and the AEC industry [55]. It also covers concepts and methods such as safety climate [56], the psychology of expatriates [57], construction safety management [58], and construction workers' safety attitudes [59]. Additionally, extensive networks and systems like transportation networks and bridge systems [7,60–66], construction supply chain and supply chain systems [67–71], safety networks and safety systems [72,73], and infrastructure and infrastructure systems [74–77] are covered. Social and community impacts are also significant, with entries such as communities [78–80] and high-density cities [81]. It should be noted that teams [82], workers [83–86], and suppliers [87,88] are included in social and community impacts as part of the community composition structure. These topics generally focus on broader, more theoretical concerns or systemic issues involving theoretical or methodological discussions.

3.1.3. Temporal Distribution of Resilience Subjects

Figure 2 shows the trend of the subject categorization of resilience from the perspective of temporal distribution. The x-axis indicates the publication year, while the y-axis stands for the total number of related samples each year. This figure reveals that the specific class is predominantly distributed from 2017 to 2020, with a decreasing trend after 2020. However, for the general class, there is a noticeable increase in entries starting around 2014, peaking in 2023, and then showing a slight decline in 2024. Given that the data were collected in the first half of 2024, the statistical sample size for 2024 is predicted to be more than 12 articles, matching the overall upward trend of the general class.

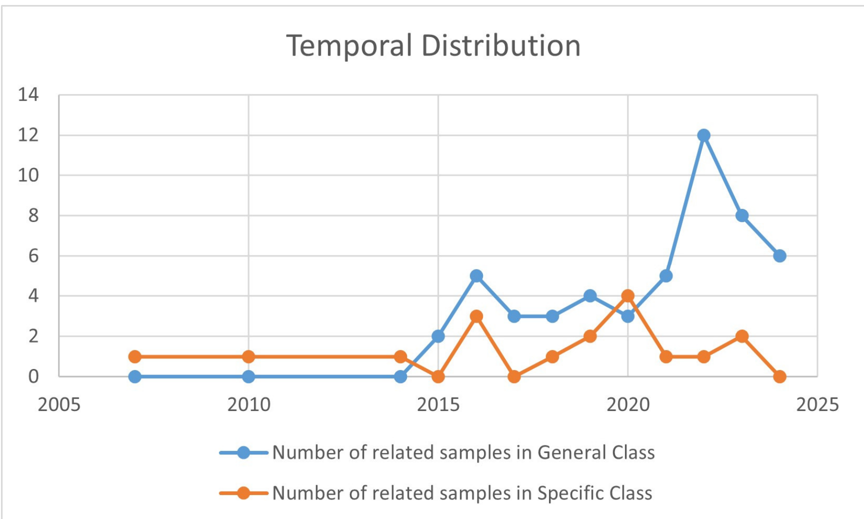

Figure 2. The temporal distribution of object classes.

3.2. The Impact Factors

Impact factors are challenges and uncertainties that cause the subject of resilience to change or try to maintain its state [6]. Unlike the subject of resilience, the study of impact factors may constitute a situation where one sample contains multiple impact factors. As shown in Table 3, these factors can be broadly categorized into natural and environmental factors and human and social factors. The quantity of each subcategory represents the number of related samples. Natural and environmental factors encompass geological, climatic, and biological events that can significantly disrupt ecosystems and human societies. Human and social factors, on the other hand, involve occupational stress, systemic risks, health crises, and societal disruptions, all of which stem from human activities and social dynamics. Human and external factors were involved in 70% of the studies, while natural and environmental factors were involved in less than 40%. Of these, uncertainties contributed the largest share, accounting for more than a quarter of the total.

Table 3. Categorized summary table of impact factors.

Main Categories	Subcategories	Number of Samples	Total
Natural and environmental factors	Geological events	16	27
	Climate and weather events	8	
	Biological events	3	
Human and external factors	Economic and supply chain risks	3	49
	Job and workplace-related risks	6	
	Security and safety risks	10	
	System and infrastructure risks	11	
	Uncertainties	19	

3.2.1. Natural and Environmental Factors

Natural and environmental factors encompass a wide range of events and conditions that can impact both the natural world and human societies. These factors include geological events such as earthquakes, seismic hazards, and tsunamis, which can result in serious destruction of infrastructure and endangerment of human life [89]. Climatic and weather events, including climate alterations and extreme weather events like hurricanes and floods, are increasingly linked to global climate change and have far-reaching impacts on ecosystems and communities. Additionally, biological events such as pandemics, exemplified by the COVID-19 emergency, highlight the vulnerability of human populations to infectious diseases that can rapidly spread and disrupt social and economic systems [90]. Environmental hazards, including natural disasters and multi-hazard scenarios, underscore the complexity and unpredictability of these risks, necessitating comprehensive disaster preparedness and resilience strategies [91].

3.2.2. Human and External Factors

Human and social factors involve a myriad of challenges and uncertainties that stem from societal dynamics and human activities. Economic and supply chain risks involve market and logistical vulnerabilities that can lead to economic shocks, affecting global trade and stability. Job- and workplace-related risks, such as job insecurity, psychological stress, and construction hazards, directly affect worker well-being and productivity [92]. Security and safety risks arise from human actions, including negligence and deliberate threats, necessitating robust security measures and safety standards to protect individuals and communities. System and infrastructure risks, including unforeseen safety risks, supply chain vulnerabilities, and system complexity, highlight the fragility of interconnected systems and the potential for cascading failures in the face of disruptions. Uncertainties refer to all unknowable and uncontrollable unknowns in addition to the listed potential risks. Samples are counted in this subcategory only if the study corresponding to the sample explicitly suggests that the influencing factors are uncertainties. Effective management of these risks requires a comprehensive approach involving prevention, mitigation, and preparedness to ensure the resilience and stability of societal and economic systems.

3.2.3. Temporal Distribution of Impact Factors

As shown in Figure 3, the trend analysis conducted between natural and environmental factors versus human and external factors from 2007 to 2024 reveals distinct patterns. Natural and environmental factors fluctuate without a consistent trend, indicating their unpredictable nature, with notable peaks, as in 2016, and periods of no occurrences, as in 2024. In contrast, human and external factors show a clear and steady increase over the years, especially after 2015, culminating in high frequencies in 2022 and 2023. This result indicates a rising influence of human activities and external disruptions, suggesting that these factors are becoming more predominant in shaping risk landscapes and necessitating enhanced strategies for management and adaptation.

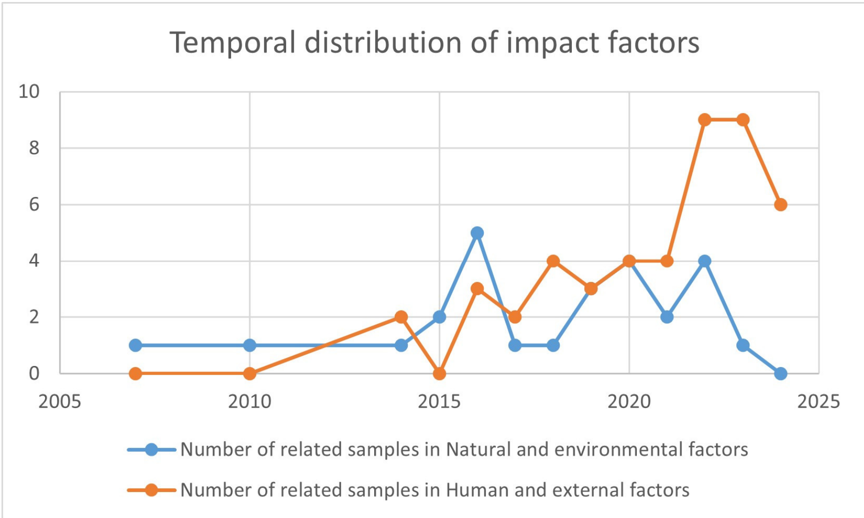

Figure 3. The temporal distribution of impact factors.

3.3. Capabilities of the Subject

The capabilities listed can be organized into two primary classifications: Management and Operations and Performance and Development, each with several sub-classifications. These categories help one focus on specific areas of organizational and operational activities critical for both immediate functionality and long-term strategic growth. As shown in Table 4, Management and Operations account for 60 samples, constituting almost 80% of the total. A trend toward greater popularity of Management and Operations can be seen in the numbers of samples.

Table 4. Categorized summary table of capabilities of the subjects.

Main Categories	Subcategories	Number of Samples	Total
Management and Operations	Safety and Risk Management	32	60
	Operational Management	21	
	Human and Community Management	5	
	Resource and Inventory Management	2	
Performance and Development	Structural and System Performance	7	17
	Network Performance	2	
	Sustainability and Environmental Management	6	
	Quality and Improvement Management	2	

3.3.1. Management and Operations

Management and Operations covers aspects critical to ensuring efficient and safe daily operations, managing risks, and handling functional requirements within organizations or systems. This classification includes subcategories such as Safety and Risk Management, which focuses on establishing protocols and strategies to manage safety concerns and risks effectively, and Operational Management, which ensures that daily operations, services, and project management run smoothly and efficiently. Additionally, Functional Management ensures the operability of systems and processes, Human and Community Management addresses workforce dynamics and community relations, and Resource and Inventory Management handles physical and human resources, ensuring adequate resource allocation.

3.3.2. Performance and Development

Performance and Development is geared toward improving and developing structural integrity, network systems, and sustainability for long-term improvement and stability. This classification includes Structural and System Performance, targeting the physical and systemic integrity of operations, and Network Performance, which focuses on the efficiency and robustness of interconnected systems and networks. Furthermore, Sustainability and Environmental Management enhances sustainability and environmental stewardship, aligning daily operations with broader Sustainable Development Goals, while Quality and Improvement Management maintains high standards of quality and allows continuous improvements in processes and outcomes.

Finally, Comfort and Well-being is a sub-classification that focuses on the environmental conditions and well-being aspects of spaces, such as thermal comfort, essential for the health and efficiency of individuals within the environment. These detailed sub-classifications allow for a more nuanced understanding and targeted management of various aspects of organizational functioning, each addressing specific needs and goals that contribute to overall operational excellence and strategic development.

3.3.3. Temporal Distribution of Subject Capabilities

The data in Figure 4 from 2007 to 2024 reveal a fluctuating but generally upward trend for Management and Operations, with a notable surge in 2016 and another peak in 2023. Initially, there was a steady state, with one instance every few years, suggesting a stable period. However, the significant increase in 2016 indicates a potential expansion or a shift in focus within the organization. The subsequent years show variability, with the highest number of instances occurring in 2023, which could imply a period of increased activity or growth. The drop in 2024 might signal a strategic reassessment or a response to changing circumstances.

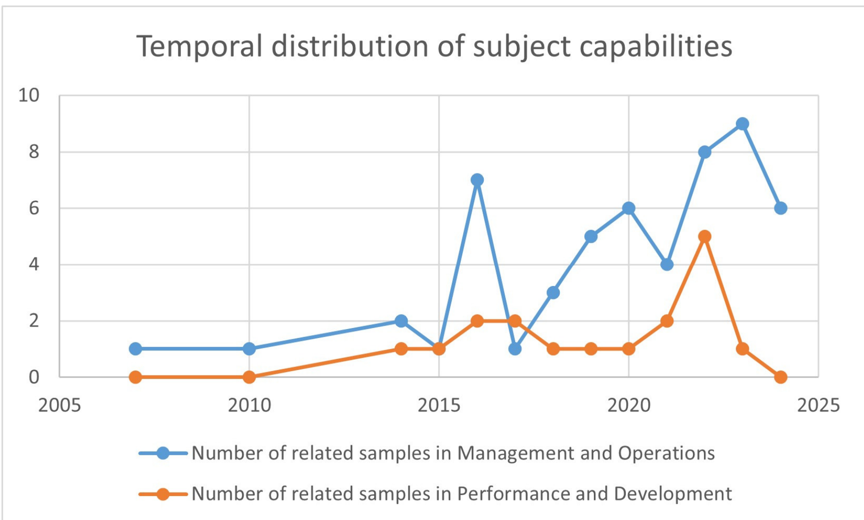

Figure 4. Temporal distribution of subject capabilities.

On the other hand, the Performance and Development category has no instances until 2014, after which it shows a gradual increase, peaking in 2022, suggesting that an organization began to prioritize performance and development later in the timeline, possibly in response to evolving needs or market conditions. The sharp decline to zero instances in 2024 is quite dramatic and could indicate a strategic decision to halt or restructure these activities. This could be due to resource allocation, a change in organizational goals, or external factors influencing the focus areas of an organization.

4. Discussion

As with other systematic reviews [93,94], this section addresses the research questions from the introduction: How has the definition of resilience evolved within the construction industry in response to the VUCA environment? What emerging trends and strategies can be identified to enhance resilience in the construction sector amidst increasing uncertainty and complexity?

By analyzing the above three aspects of resilience quantitatively and temporally, we found that resilience has evolved from focusing on specific defined shocks to addressing the complexities introduced by diverse and unpredictable disruptions, particularly within VUCA environments [95]. This shift necessitates a refined understanding of functional resilience across various system levels, especially in the context of digital transformation and Industry 4.0. This paper explores this evolution and proposes new research directions to enhance resilience strategies, incorporating advanced methodologies like data-driven modeling [96] and federated simulations [97].

Although there are articles referring to complex resilient systems [98] and redefining construction with resilience [99], the results identify ambiguities in all three perspectives of these definitions due to their broad concepts. Each sample analyzed reveals a flaw in the research design: at least one perspective of the fuzzy resilience concept is present in each sample. This issue may contribute to the gradual blurring of resilience's evolution in the construction industry.

It is proposed that resilience research in this field should be redefined, particularly with respect to these three dimensions. Future studies should consider a research framework based on these aspects.

For instance, when focusing on resilience in the construction industry, the first step is to clarify the subject of resilience. Table 2 can serve as a thematic reference. Once the first dimension is defined, the next question is the nature of the impact factors, which can be found in Table 3. Finally, researchers should consider the specific functions of the subject, with Table 4 offering useful ideas. By addressing these three questions, researchers will gain a clearer understanding of their study's focus, providing a solid theoretical framework for systematically investigating specific issues. This approach enables a more in-depth and comprehensive examination of the subject matter.

In the next four subsections, an analysis of the results, conclusions, and future trends will be elaborated. In Section 4.1, it is expressed that the concept of the subject of resilience and resilience itself becomes gradually more ambiguous over time. Moreover, this ambiguity tends to be complex and diverse. Section 4.2 analyzes resilience from the perspective of impact factors and subject functions, and the results show that the uncertainty of impact factors leads to a lack of clarity of the subject's function and that research tends to focus more on functional resilience. Section 4.3 stresses the necessity of redefining the resilience concept to adapt to VUCA based on the discussion in Sections 4.1 and 4.2. Section 4.4 proposes the direction of future developments and suggestions.

4.1. The Evolution and Ambiguity of the Early Concept of Resilience

In examining the evolution of the concept of resilience, early research concentrated on a particular system's resilience when subjected to a particular shock, such as an earthquake [33,65,79]. At this time, the functional failure of the system under shock was readily apparent, and the concept of resilience was relatively straightforward to grasp. Nevertheless, over time, the ambiguity surrounding the concept of resilience gradually developed, and it persists to this day [100–102]. This ambiguity primarily arises from the diversity of shock types and the uncertainty of their resulting functional failures.

The general class, which makes up most of the subjects of resilience, has a wide range of meanings in resilience research. The subject of research on resilience may be generalized in terms of concepts, scope, or the subject itself despite the specificity of the name. In addition, there is some ambiguity about the types of research on impacts and the types of capabilities of the subject, possibly because the rapid development of the engineering field has led to many different directions in the study of resilience. These new directions and the gradually changing environment have made the types of impacts and the subject's capabilities more complex and diverse.

4.2. Complexity of Impact Types and Functional Failures

The current lack of clarity regarding the types of shocks experienced leads to functional failures that are similarly unclear. For instance, disparate shocks, including epidemics, earthquakes, and political upheavals, can precipitate disparate functional failures in each system, necessitating disparate resilience strategies. What is more, the resilience of the healthcare system in the event of an epidemic outbreak is principally contingent upon its capacity to cope with the influx of patients, whereas the resilience of infrastructure in the event of an earthquake is predicated upon its ability to withstand and recover from such an event. Political unrest has the potential to result in disruptions to supply chains, thereby necessitating the demonstration of resilience by logistics and management systems in a variety of forms.

Furthermore, there is a growing tendency in research to focus more on functional resilience than systemic resilience. For instance, within safety management, functions cut across a multitude of system levels (e.g., industry, project, and organizational levels). Consequently, it is apparent that different subsystems necessitate varying levels of resilience for the same function. At the project level, safety management may necessitate the capacity to respond expeditiously to incidents. At the industry level, it requires the formulation of comprehensive safety standards and the establishment of regulatory mechanisms. Functional resilience is, therefore, a more complex concept than simple system resilience and requires more detailed analysis and research.

4.3. Redefining the Concept of Resilience in a VUCA Environment

In the context of the current trend of Industry 4.0 and digital transformation [103], the evolution of user functional requirements presents a challenge regarding the ability to meet both theoretical and practical resilience needs by selecting the initial function of the system itself as the resilience object. Furthermore, the prevalence of volatile, uncertain, complex, and ambiguous (VUCA) environments serves to compound this challenge. In such environments, traditional management and decision-making models are often unable to cope with the challenges presented, necessitating a redefinition of the resilience concept.

From a safety management perspective, the traditional definition of resilience is no longer applicable. The advent of Industry 4.0 has brought with it a great deal of automation and data-driven decision-making. In the context of digital transformation, it is, therefore, imperative for systems to be highly resilient in the face of unpredictable change [104]. The safety management resilience concept has evolved to encompass not only the ability to respond to a single incident but also the capacity to synthesize multiple risks in a continuously changing environment.

Consequently, a precise resilience concept will facilitate the development of related theories and the construction of related systems. We propose a redefinition of resilience from multiple perspectives, including system resilience and functional resilience, tailored to specific application scenarios and environments. For instance, resilience can be categorized into distinct types, including structural resilience, operational resilience, and supply chain resilience, each of which can be analyzed in the context of specific challenges and requirements.

A holistic study can be conducted based on these definitions to achieve a more thorough insight into system resilience and enhance it in a more effective manner. This can be achieved by studying the association between subsystems and the distribution of functions among different subsystems. Furthermore, a comprehensive system resilience analysis can be achieved by utilizing techniques such as high-level architecture (HLA) federated simulation [105]. This approach allows researchers to simulate and evaluate different resilience strategies in a virtual environment, thus providing reliable theoretical and data support for practical applications. It does not conflict with other research methods, but it does require researchers to fully consider the internal manifestations of resilience from these three perspectives when selecting a research framework. However, this method also has the problem of being time-sensitive. As the environment changes, the three angles of the construction industry's resilience content are also constantly changing. When researchers conduct research, they need to determine the latest factors of the three angles in advance.

In conclusion, the redefinition of the concept of resilience in the VUCA environment is not only a requirement for academic research but also an urgent need in practice. Through systematic, functional, and multidimensional resilience research, a more solid foundation can be provided to cope with future uncertainties.

4.4. Future Directions and Suggestions

More and more resilience studies are geared toward using data-driven methods [106] to improve and develop resilience research. To advance the field of future resilience research, it is essential to adopt a multi-perspective approach, focusing on the resilience of structures, operations, and supply chains while emphasizing functional resilience in complex systems. Researchers might conduct case studies across different industries to identify unique resilience requirements or use systems thinking to map interdependencies and identify critical leverage points. To develop adaptive strategies tailored to VUCA environments, researchers could leverage big data, machine learning, and network analysis to predict disruptions and optimize resilience. Implementing machine learning algorithms and BIM and AI [107] to analyze historical data and predict potential disruptions in construction management is recommended. HLA federated simulations can provide a robust platform for testing resilience strategies under a variety of scenarios. To address deviations, it is necessary to standardize methodologies, understand context-specific variability, and integrate evolving resilience concepts to ensure consistent and applicable findings are obtained. Establishing a dedicated think tank with which to monitor and evaluate emerging resilience research and trends might be a good research idea. Organizing regular workshops and symposia with experts from academia, industry, and governmental bodies to exchange ideas and update resilience strategies could be another good research direction. This comprehensive strategy will facilitate the practical implementation of resilience in diverse and dynamic settings.

5. Conclusions

This systematic review aims to evaluate resilience in the construction industry from three definitional perspectives: the subject of resilience, the influencing factors of uncertainty, and the roles of the resilient subject. To ensure the comprehensiveness of this review, 70 research articles from the Scopus and Web of Science databases were selected as samples according to the PRISMA principles. This review categorizes the subjects of resilience into specific and general classes, revealing a diverse array of research focusing on both tangible projects and broader, systemic themes. The analysis of influencing factors underscores the dichotomy between natural and environmental and human and social factors, while the discussion on subject functions highlights the critical abilities to maintain or recover from challenges.

We found that the resilience concept in the construction industry is becoming ambiguous. The subject of resilience is gradually becoming general. The concept of the subject tends to become more abstract, and the scope of research is becoming broader. The types of impacts are also changing from a single natural disaster to more vague uncertainties and unknown challenges. The study of systemic functioning is complicated by uncertainty about the form of impact. In addition, more studies tend to correspond to the functional toughness of multiple systems rather than the systemic toughness of a single system. This tendency also complicates the research dimension of resilience becoming complex. As Industry 4.0 and digital transformation advance, the importance of functional resilience across various system levels has become increasingly evident, surpassing traditional management and decision-making models.

Based on these findings, we advocate the need to redefine the resilience concept in a VUCA environment from multiple perspectives. In light of environmental uncertainty and the complexity of resilience research, redefining resilience from specific perspectives has been defined as a target to help make resilience research more systematized, functionalized, and comprehensive and provide theoretical support for future research.

To enhance resilience strategies, we propose leveraging advanced methodologies such as big data, machine learning, and HLA federated simulations. These approaches can be used to predict disruptions and optimize resilience strategies, providing a robust theoretical and practical foundation with which to cope with future uncertainties. This comprehensive strategy is designed to facilitate the practical implementation of resilience in diverse and dynamic settings.

Although this review systematically analyzes the evolution and future direction of resilience in the construction industry, the following problem may still have an influence. The environment of the construction industry is constantly changing, which creates chronological uncertainty in the study of resilience. Therefore, this research may not be authoritative for newly derived concepts in the construction industry.

Funding: This research was funded by the National Natural Science Foundation of China: NSFC-72171048, and NSFC-72101053, and Jiangsu Social Science Fund (General project) under Grant No. 23GLB028.

Data Availability Statement: All data used are available and transparent. If needed, they can be accessed via contacting the following email: li_jinjing2@163.com.

Acknowledgments: All authors of this study are grateful to all staff involved in retrieving and extracting the information and to all those who provided resources.

Conflicts of Interest: All authors report no conflicts of interest.

References

1. Zhang, B.; Mei, Y.; Xiong, Y.; Liu, Y. Can Digital Transformation Promote Service Innovation Performance of Construction Enterprises? The Mediating Role of Dual Innovation. *Sustainability* **2024**, *16*, 1176. [CrossRef]
2. Murtagh, N.; Scott, L.; Fan, J. Sustainable and Resilient Construction: Current Status and Future Challenges. *J. Clean. Prod.* **2020**, *268*, 122264. [CrossRef]
3. Cambraia, F.B.; Saurin, T.A.; Bulhões, I.R.; Formoso, C.T. A Knowledge Framework of Participation Supportive of Resilient and Safe Construction Projects: A Systematic Review. *Saf. Sci.* **2024**, *175*, 106494. [CrossRef]
4. Ranasinghe, U.; Jefferies, M.; Davis, P.; Pillay, M. Resilience Engineering Indicators and Safety Management: A Systematic Review. *Saf. Health Work* **2020**, *11*, 127–135. [CrossRef] [PubMed]
5. Robbins, J.D.; Wang, J.; Esmaeili, B. Review of Safety Resilience in Construction: Current Research Status, Challenges, and Future Needs. In Proceedings of the Construction Research Congress 2022: Health and Safety, Workforce, and Education, Arlington, VA, USA, 9–12 March 2022; Jazizadeh, F., Shealy, T., Garvin, M.J., Eds.; Amer Soc Civil Engineers: New York, NY, USA, 2022; pp. 393–402.
6. Bhamra, R.; Dani, S.; Burnard, K. Resilience: The Concept, a Literature Review and Future Directions. *Int. J. Prod. Res.* **2011**, *49*, 5375–5393. [CrossRef]
7. Bocchini, P.; Frangopol, D.M.; Ummenhofer, T.; Zinke, T. Resilience and Sustainability of Civil Infrastructure: Toward a Unified Approach. *J. Infrastruct. Syst.* **2014**, *20*, 04014004. [CrossRef]
8. Holling, C.S. Resilience and Stability of Ecological Systems. *Annu. Rev. Ecol. Evol. Syst.* **1973**, *4*, 1–23. [CrossRef]
9. Annarelli, A.; Nonino, F. Strategic and Operational Management of Organizational Resilience: Current State of Research and Future Directions. *Omega* **2016**, *62*, 1–18. [CrossRef]
10. Pires Ribeiro, J.; Barbosa-Povoa, A. Supply Chain Resilience: Definitions and Quantitative Modelling Approaches—A Literature Review. *Comput. Ind. Eng.* **2018**, *115*, 109–122. [CrossRef]

11. Conz, E.; Magnani, G. A Dynamic Perspective on the Resilience of Firms: A Systematic Literature Review and a Framework for Future Research. *Eur. Manag. J.* **2020**, *38*, 400–412. [CrossRef]
12. Zhou, Y.; Wang, J.; Yang, H. Resilience of Transportation Systems: Concepts and Comprehensive Review. *IEEE Trans. Intell. Transp. Syst.* **2019**, *20*, 4262–4276. [CrossRef]
13. Liu, W.; Song, Z. Review of Studies on the Resilience of Urban Critical Infrastructure Networks. *Reliab. Eng. Syst. Saf.* **2020**, *193*, 106617. [CrossRef]
14. Foster, K.; Roche, M.; Delgado, C.; Cuzzillo, C.; Giandinoto, J.-A.; Furness, T. Resilience and Mental Health Nursing: An Integrative Review of International Literature. *Int. J. Ment. Health Nurs.* **2019**, *28*, 71–85. [CrossRef]
15. Quitana, G.; Molinos-Senante, M.; Chamorro, A. Resilience of Critical Infrastructure to Natural Hazards: A Review Focused on Drinking Water Systems. *Int. J. Disaster Risk Reduct.* **2020**, *48*, 101575. [CrossRef]
16. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ* **2021**, *372*, n71. [CrossRef] [PubMed]
17. Afzal, M.; Li, R.Y.M.; Shoaib, M.; Ayyub, M.F.; Tagliabue, L.C.; Bilal, M.; Ghafoor, H.; Manta, O. Delving into the Digital Twin Developments and Applications in the Construction Industry: A PRISMA Approach. *Sustainability* **2023**, *15*, 16436. [CrossRef]
18. Li, R.Y.M.; Li, Y.L.; Crabbe, M.J.C.; Manta, O.; Shoaib, M. The Impact of Sustainability Awareness and Moral Values on Environmental Laws. *Sustainability* **2021**, *13*, 5882. [CrossRef]
19. Liao, L.; Yang, C.; Quan, L. Construction Supply Chain Management: A Systematic Literature Review and Future Development. *J. Clean. Prod.* **2023**, *382*, 135230. [CrossRef]
20. Ning, Y.; Gao, S. A Resilience Framework to Explorative Quality Management in Innovative Building Projects. *J. Eng. Technol. Manag.* **2021**, *62*, 101654. [CrossRef]
21. Wedawatta, G.; Ingirige, B.; Amaratunga, D. Building up resilienc e of construction sector smes and their supply chains to extreme weather events. *Int. J. Strateg. Prop. Manag.* **2010**, *14*, 362–375. [CrossRef]
22. Ranasinghe, U.; Jefferies, M.; Davis, P.; Pillay, M. Enabling a Resilient Work Environment: An Analysis of Causal Relationships between Resilience Engineering Factors in Construction Refurbishment Projects. *J. Constr. Eng. Manage.* **2023**, *149*, 04023078. [CrossRef]
23. Zhang, W.; Dong, H.; Wen, J.; Han, Q. A Resilience-Based Decision Framework for Post-Earthquake Restoration of Bridge Networks under Uncertainty. *Struct. Infrastruct. Eng.* **2023**, 1–16. [CrossRef]
24. Li, Y.; Dong, Y.; Frangopol, D.M.; Gautam, D. Long-Term Resilience and Loss Assessment of Highway Bridges under Multiple Natural Hazards. *Struct. Infrastruct. Eng.* **2020**, *16*, 626–641. [CrossRef]
25. Dong, Y.; Frangopol, D.M. Probabilistic Time-Dependent Multihazard Life-Cycle Assessment and Resilience of Bridges Considering Climate Change. *J. Perform. Constr. Facil.* **2016**, *30*, 04016034. [CrossRef]
26. Akiyama, M.; Frangopol, D.M.; Ishibashi, H. Toward Life-Cycle Reliability-, Risk- and Resilience-Based Design and Assessment of Bridges and Bridge Networks under Independent and Interacting Hazards: Emphasis on Earthquake, Tsunami and Corrosion. *Struct. Infrastruct. Eng.* **2020**, *16*, 26–50. [CrossRef]
27. Shafieezadeh, A.; Ivey Burden, L. Scenario-Based Resilience Assessment Framework for Critical Infrastructure Systems: Case Study for Seismic Resilience of Seaports. *Reliab. Eng. Syst. Saf.* **2014**, *132*, 207–219. [CrossRef]
28. Verschuur, J.; Pant, R.; Koks, E.; Hall, J. A Systemic Risk Framework to Improve the Resilience of Port and Supply-Chain Networks to Natural Hazards. *Marit. Econ. Logist.* **2022**, *24*, 489–506. [CrossRef]
29. John, A.; Yang, Z.; Riahi, R.; Wang, J. A Risk Assessment Approach to Improve the Resilience of a Seaport System Using Bayesian Networks. *Ocean Eng.* **2016**, *111*, 136–147. [CrossRef]
30. Azadeh, A.; Salehi, V.; Arvan, M.; Dolatkhah, M. Assessment of Resilience Engineering Factors in High-Risk Environments by Fuzzy Cognitive Maps: A Petrochemical Plant. *Saf. Sci.* **2014**, *68*, 99–107. [CrossRef]
31. Xiong, C.; Huang, J.; Lu, X. Framework for City-scale Building Seismic Resilience Simulation and Repair Scheduling with Labor Constraints Driven by Time–History Analysis. *Comput. Aided Civ. Eng* **2020**, *35*, 322–341. [CrossRef]
32. Katal, A.; Mortezazadeh, M.; Wang, L. (Leon) Modeling Building Resilience against Extreme Weather by Integrated CityFFD and CityBEM Simulations. *Appl. Energy* **2019**, *250*, 1402–1417. [CrossRef]
33. Bruneau, M.; Reinhorn, A. Exploring the Concept of Seismic Resilience for Acute Care Facilities. *Earthq. Spectra* **2007**, *23*, 41–62. [CrossRef]
34. Osman, M.M.; Sevinc, H. Adaptation of Climate-Responsive Building Design Strategies and Resilience to Climate Change in the Hot/Arid Region of Khartoum, Sudan. *Sustain. Cities Soc.* **2019**, *47*, 101429. [CrossRef]
35. Feng, X.; Xiu, C.; Bai, L.; Zhong, Y.; Wei, Y. Comprehensive Evaluation of Urban Resilience Based on the Perspective of Landscape Pattern: A Case Study of Shenyang City. *Cities* **2020**, *104*, 102722. [CrossRef]
36. Angulo, A.M.; Mur, J.; Trívez, F.J. Measuring Resilience to Economic Shocks: An Application to Spain. *Ann. Reg. Sci.* **2018**, *60*, 349–373. [CrossRef]
37. Molina Hutt, C.; Almufti, I.; Willford, M.; Deierlein, G. Seismic Loss and Downtime Assessment of Existing Tall Steel-Framed Buildings and Strategies for Increased Resilience. *J. Struct. Eng.* **2016**, *142*, C4015005. [CrossRef]
38. Azmi, N.A.; Sweis, G.; Sweis, R.; Sammour, F. Exploring Implementation of Blockchain for the Supply Chain Resilience and Sustainability of the Construction Industry in Saudi Arabia. *Sustainability* **2022**, *14*, 6427. [CrossRef]

39. Yao, H.; Wang, K. Concentrated or Dispersed: The Effects of Subcontracting Organizational Arrangements on Construction Project Resilience. *J. Manag. Eng.* **2024**, *40*, 04024017. [CrossRef]
40. Gerami Seresht, N. Enhancing Resilience in Construction against Infectious Diseases Using Stochastic Multi-Agent Approach. *Autom. Constr.* **2022**, *140*, 104315. [CrossRef]
41. Trinh, M.T.; Feng, Y.; Mohamed, S. Framework for Measuring Resilient Safety Culture in Vietnam's Construction Environment. *J. Constr. Eng. Manag.* **2019**, *145*, 04018127. [CrossRef]
42. Wang, D.; Wu, Y.; Zhang, K. Interplay of Resources and Institutions in Improving Organizational Resilience of Construction Projects: A Dynamic Perspective. *EMJ-Eng. Manag. J.* **2023**, *35*, 346–357. [CrossRef]
43. He, Z.; Wang, G.; Chen, H.; Zou, Z.; Yan, H.; Liu, L. Measuring the Construction Project Resilience from the Perspective of Employee Behaviors. *Buildings* **2022**, *12*, 56. [CrossRef]
44. Peñaloza, G.A.; Saurin, T.A.; Formoso, C.T. Monitoring Complexity and Resilience in Construction Projects: The Contribution of Safety Performance Measurement Systems. *Appl. Ergon.* **2020**, *82*, 102978. [CrossRef]
45. Hilu, K.A.; Hiyassat, M.A. Qualitative Assessment of Resilience in Construction Projects. *Constr. Innov.* **2023**, *24*, 1297–1319. [CrossRef]
46. Milat, M.; Knezić, S.; Sedlar, J. Resilient Scheduling as a Response to Uncertainty in Construction Projects. *Appl. Sci.* **2021**, *11*, 6493. [CrossRef]
47. Hamerski, D.C.; Saurin, T.A.; Formoso, C.T.; Isatto, E.L. The Contributions of the Last Planner System to Resilient Performance in Construction Projects. *Constr. Manag. Econ.* **2024**, *42*, 328–345. [CrossRef]
48. Wang, D.; Wang, P.; Liu, Y. The Emergence Process of Construction Project Resilience: A Social Network Analysis Approach. *Buildings* **2022**, *12*, 822. [CrossRef]
49. Trinh, M.T.; Feng, Y. A Maturity Model for Resilient Safety Culture Development in Construction Companies. *Buildings* **2022**, *12*, 733. [CrossRef]
50. Feng, Y.; Trinh, M.T. Developing Resilient Safety Culture for Construction Projects. *J. Constr. Eng. Manag.* **2019**, *145*, 04019069. [CrossRef]
51. Saldanha, M.C.W.; Araújo, L.L.F.; Arcuri, R.; Vidal, M.C.R.; De Carvalho, P.V.R.; De Carvalho, R.J.M. Identifying Routes and Organizational Practices for Resilient Performance: A Study in the Construction Industry. *Cogn. Technol. Work* **2022**, *24*, 521–535. [CrossRef]
52. Trinh, M.T.; Feng, Y. Impact of Project Complexity on Construction Safety Performance: Moderating Role of Resilient Safety Culture. *J. Constr. Eng. Manag.* **2020**, *146*, 04019103. [CrossRef]
53. Chih, Y.-Y.; Hsiao, C.Y.-L.; Zolghadr, A.; Naderpajouh, N. Resilience of Organizations in the Construction Industry in the Face of COVID-19 Disturbances: Dynamic Capabilities Perspective. *J. Manag. Eng.* **2022**, *38*, 04022002. [CrossRef]
54. Malik, A.; Khan, K.I.A.; Qayyum, S.; Ullah, F.; Maqsoom, A. Resilient Capabilities to Tackle Supply Chain Risks: Managing Integration Complexities in Construction Projects. *Buildings* **2022**, *12*, 1322. [CrossRef]
55. Nassereddine, H.; Seo, K.W.; Rybkowski, Z.K.; Schranz, C.; Urban, H. Propositions for a Resilient, Post-COVID-19 Future for the AEC Industry. *Front. Built Environ.* **2021**, *7*, 687021. [CrossRef]
56. Chen, Y.; McCabe, B.; Hyatt, D. A Resilience Safety Climate Model Predicting Construction Safety Performance. *Saf. Sci.* **2018**, *109*, 434–445. [CrossRef]
57. Gao, L.; Luo, X.; Wang, Y.; Zhang, N.; Deng, X. Retention in Challenging International Construction Assignments: Role of Expatriate Resilience. *J. Constr. Eng. Manag.* **2024**, *150*, 04023158. [CrossRef]
58. Liu, K.; Liu, Y.; Kou, Y. Study on Construction Safety Management in Megaprojects from the Perspective of Resilient Governance. *Saf. Sci.* **2024**, *173*, 106442. [CrossRef]
59. Xu, S.; Lin, B.; Zou, P.X.W. Examining Construction Group's Safety Attitude Resilience under Major Disruptions: An Agent-Based Modelling Approach. *Saf. Sci.* **2023**, *161*, 106071. [CrossRef]
60. Cai, B.; Xie, M.; Liu, Y.; Liu, Y.; Feng, Q. Availability-Based Engineering Resilience Metric and Its Corresponding Evaluation Methodology. *Reliab. Eng. Syst. Saf.* **2018**, *172*, 216–224. [CrossRef]
61. Kilanitis, I.; Sextos, A. Integrated Seismic Risk and Resilience Assessment of Roadway Networks in Earthquake Prone Areas. *Bull. Earthq. Eng.* **2019**, *17*, 181–210. [CrossRef]
62. Wang, H.; Zhou, J.; Dun, Z.; Cheng, J.; Li, H.; Dun, Z. Resilience Evaluation of High-Speed Railway Subgrade Construction Systems in Goaf Sites. *Sustainability* **2022**, *14*, 7806. [CrossRef]
63. Zhang, W.; Wang, N.; Nicholson, C. Resilience-Based Post-Disaster Recovery Strategies for Road-Bridge Networks. *Struct. Infrastruct. Eng.* **2017**, *13*, 1404–1413. [CrossRef]
64. Zhang, W.; Wang, N. Resilience-Based Risk Mitigation for Road Networks. *Struct. Saf.* **2016**, *62*, 57–65. [CrossRef]
65. Dong, Y.; Frangopol, D.M. Risk and Resilience Assessment of Bridges under Mainshock and Aftershocks Incorporating Uncertainties. *Eng. Struct.* **2015**, *83*, 198–208. [CrossRef]
66. Alipour, A.; Shafei, B. Seismic Resilience of Transportation Networks with Deteriorating Components. *J. Struct. Eng.* **2016**, *142*, C4015015. [CrossRef]
67. Chen, Z.; Hammad, A.W.A.; Alyami, M. Building Construction Supply Chain Resilience under Supply and Demand Uncertainties. *Autom. Constr.* **2024**, *158*, 105190. [CrossRef]

68. Xie, D.; Xin, J.; Wang, H.; Xiao, L. Identifying Critical Factors Affecting the Resilience of Additive Manufacturing Architecture Supply Chain. *Buildings* **2023**, *13*, 997. [CrossRef]
69. Cherian, T.M.; Mathivathanan, D.; Arun SJ, C.J.; Ramasubramaniam, M.; Alathur, S. Influence of Supply Chain Resilience, Information Technology Capabilities and Agility on Cost and Delivery Performance in Construction Supply Chains: An Indian Perspective. *Int. J. Logist. Manag.* **2022**, *34*, 1050–1076. [CrossRef]
70. Ekanayake, E.M.A.C.; Shen, G.Q.P.; Kumaraswamy, M.M.; Owusu, E.K.; Saka, A.B. Modeling Supply Chain Resilience in Industrialized Construction: A Hong Kong Case. *J. Constr. Eng. Manag.* **2021**, *147*, 05021009. [CrossRef]
71. Cheng, S.; Zhou, X.; Zhang, Y.; Duan, M.; Gao, J. Study on Resilience Factors and Enhancement Strategies in Prefabricated Building Supply Chains. *Buildings* **2024**, *14*, 195. [CrossRef]
72. Wehbe, F.; Hattab, M.A.; Hamzeh, F. Exploring Associations between Resilience and Construction Safety Performance in Safety Networks. *Saf. Sci.* **2016**, *82*, 338–351. [CrossRef]
73. Guo, Q.; Amin, S.; Hao, Q.; Haas, O. Resilience Assessment of Safety System at Subway Construction Sites Applying Analytic Network Process and Extension Cloud Models. *Reliab. Eng. Syst. Saf.* **2020**, *201*, 106956. [CrossRef]
74. Argyroudis, S.A.; Mitoulis, S.A.; Chatzi, E.; Baker, J.W.; Brilakis, I.; Gkoumas, K.; Vousdoukas, M.; Hynes, W.; Carluccio, S.; Keou, O.; et al. Digital Technologies Can Enhance Climate Resilience of Critical Infrastructure. *Clim. Risk Manag.* **2022**, *35*, 100387. [CrossRef]
75. Iannacone, L.; Sharma, N.; Tabandeh, A.; Gardoni, P. Modeling Time-Varying Reliability and Resilience of Deteriorating Infrastructure. *Reliab. Eng. Syst. Saf.* **2022**, *217*, 108074. [CrossRef]
76. Lounis, Z.; McAllister, T.P. Risk-Based Decision Making for Sustainable and Resilient Infrastructure Systems. *J. Struct. Eng.* **2016**, *142*, F4016005. [CrossRef]
77. Dao, J.; Ng, S.T.; Yang, Y.; Zhou, S.; Xu, F.J.; Skitmore, M. Semantic Framework for Interdependent Infrastructure Resilience Decision Support. *Autom. Constr.* **2021**, *130*, 103852. [CrossRef]
78. Burton, H.V.; Deierlein, G.; Lallemant, D.; Lin, T. Framework for Incorporating Probabilistic Building Performance in the Assessment of Community Seismic Resilience. *J. Struct. Eng.* **2016**, *142*, C4015007. [CrossRef]
79. Franchin, P.; Cavalieri, F. Probabilistic Assessment of Civil Infrastructure Resilience to Earthquakes. *Comput. Aided Civ. Eng* **2015**, *30*, 583–600. [CrossRef]
80. Wei, W.; Mojtahedi, M.; Yazdani, M.; Kabirifar, K. The Alignment of Australia's National Construction Code and the Sendai Framework for Disaster Risk Reduction in Achieving Resilient Buildings and Communities. *Buildings* **2021**, *11*, 429. [CrossRef]
81. Yang, Y.; Ng, S.T.; Xu, F.J.; Skitmore, M. Towards Sustainable and Resilient High Density Cities through Better Integration of Infrastructure Networks. *Sustain. Cities Soc.* **2018**, *42*, 407–422. [CrossRef]
82. Jiang, S.; Ling, F.Y.Y.; Ma, G. Fostering Resilience in Project Teams: Adaptive Structuration Perspective. *J. Manag. Eng.* **2024**, *40*, 04023047. [CrossRef]
83. Lu, C.; Yu, D.; Luo, Q.; Xu, C. A Study of the Effects of Job Stress on the Psychosocial Safety Behavior of Construction Workers: The Mediating Role of Psychological Resilience. *Buildings* **2023**, *13*, 1930. [CrossRef]
84. Aasen, A.F.; Klakegg, O.J. Human Resilience and Cultural Change in the Construction Industry: Communication and Relationships in a Time of Enforced Adaptation. *Front. Built Environ.* **2023**, *9*, 1287483. [CrossRef]
85. Chen, Y.; McCabe, B.; Hyatt, D. Impact of Individual Resilience and Safety Climate on Safety Performance and Psychological Stress of Construction Workers: A Case Study of the Ontario Construction Industry. *J. Saf. Res.* **2017**, *61*, 167–176. [CrossRef] [PubMed]
86. Nwaogu, J.M.; Chan, A.P.C. The Impact of Coping Strategies and Individual Resilience on Anxiety and Depression among Construction Supervisors. *Buildings* **2022**, *12*, 2148. [CrossRef]
87. Wang, T.-K.; Zhang, Q.; Chong, H.-Y.; Wang, X. Integrated Supplier Selection Framework in a Resilient Construction Supply Chain: An Approach via Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA). *Sustainability* **2017**, *9*, 289. [CrossRef]
88. Shishodia, A.; Verma, P.; Dixit, V. Supplier Evaluation for Resilient Project Driven Supply Chain. *Comput. Ind. Eng.* **2019**, *129*, 465–478. [CrossRef]
89. Thurber, C. An Introduction to Seismology, Earthquakes, and Earth Structure. *EoS Trans.* **2003**, *84*, 209–210. [CrossRef]
90. Morse, S.S.; Mazet, J.A.; Woolhouse, M.; Parrish, C.R.; Carroll, D.; Karesh, W.B.; Zambrana-Torrelio, C.; Lipkin, W.I.; Daszak, P. Prediction and Prevention of the next Pandemic Zoonosis. *Lancet* **2012**, *380*, 1956–1965. [CrossRef]
91. Cutter, S.L.; Boruff, B.J.; Shirley, W.L. Social Vulnerability to Environmental Hazards*. *Soc. Sci. Q.* **2003**, *84*, 242–261. [CrossRef]
92. Sauter, S.L.; Murphy, L.R.; Hurrell, J.J. Prevention of Work-Related Psychological Disorders. A National Strategy Proposed by the National Institute for Occupational Safety and Health (NIOSH). *Am. Psychol.* **1990**, *45*, 1146–1158. [CrossRef] [PubMed]
93. Daboun, O.; Md Yusof, A.; Khoso, A.R. Relationship Management in Construction Projects: Systematic Literature Review. *Eng. Manag. J.* **2023**, *35*, 120–143. [CrossRef]
94. Karuppiah, K.; Sankaranarayanan, B.; Ali, S.M. A Systematic Review of Sustainable Business Models: Opportunities, Challenges, and Future Research Directions. *Decis. Anal. J.* **2023**, *8*, 100272. [CrossRef]
95. Grzybowska, K.; Tubis, A.A. Supply Chain Resilience in Reality VUCA-An International Delphi Study. *Sustainability* **2022**, *14*, 10711. [CrossRef]

96. Li, K.; Ma, J.; Gao, J.; Xu, C.; Li, W.; Mao, Y.; Jiang, S. Resilience Assessment of Urban Distribution Network Under Heavy Rain: A Knowledge- Informed Data-Driven Approach. *IEEE Access* **2023**, *11*, 63741–63750. [CrossRef]
97. Yang, Y.; Ng, S.T.; Zhou, S.; Xu, F.J.; Li, D.; Li, H. A Federated Pre-Event Community Resilience Approach for Assessing Physical and Social Sub-Systems: An Extreme Rainfall Case in Hong Kong. *Sustain. Cities Soc.* **2020**, *52*, 101859. [CrossRef]
98. Bozza, A.; Asprone, D.; Fabbrocino, F. Urban Resilience: A Civil Engineering Perspective. *Sustainability* **2017**, *9*, 103. [CrossRef]
99. Hao, H.; Bi, K.; Chen, W.; Pham, T.M.; Li, J. Towards next Generation Design of Sustainable, Durable, Multi-Hazard Resistant, Resilient, and Smart Civil Engineering Structures. *Eng. Struct.* **2023**, *277*, 115477. [CrossRef]
100. Herrera, H. Resilience for Whom? The Problem Structuring Process of the Resilience Analysis. *Sustainability* **2017**, *9*, 1196. [CrossRef]
101. Juncos, A.E. Resilience in Peacebuilding: Contesting Uncertainty, Ambiguity, and Complexity. *Contemp. Secur. Policy* **2018**, *39*, 559–574. [CrossRef]
102. Li, Y.; Lei, S.; Sun, W.; Hu, C.; Hou, Y. A Distributionally Robust Resilience Enhancement Strategy for Distribution Networks Considering Decision-Dependent Contingencies. *IEEE Trans. Smart Grid* **2024**, *15*, 1450–1465. [CrossRef]
103. Dolla, T.; Jain, K.; Delhi, V.S.K. Strategies for Digital Transformation in Construction Projects: Stakeholders' Perceptions and Actor Dynamics for Industry 4.0. *J. Inf. Technol. Constr.* **2023**, *28*, 151–175. [CrossRef]
104. Browder, R.E.; Dwyer, S.M.; Koch, H. Upgrading Adaptation: How Digital Transformation Promotes Organizational Resilience. *Strateg. Entrep. J.* **2024**, *18*, 128–164. [CrossRef]
105. Yang, Y.; Ng, S.T.; Li, N.; Xu, X.; Xu, P.; Xu, F.J. Adapting HLA-Based Co-Simulation for Interdependent Infrastructure Resilience Management. *Autom. Constr.* **2023**, *150*, 104860. [CrossRef]
106. Rathnasiri, P.; Adeniyi, O.; Thurairajah, N. Data-Driven Approaches to Built Environment Flood Resilience: A Scientometric and Critical Review. *Adv. Eng. Inform.* **2023**, *57*, 102085. [CrossRef]
107. Heidari, A.; Peyvastehgar, Y.; Amanzadegan, M. A Systematic Review of the BIM in Construction: From Smart Building Management to Interoperability of BIM & AI. *Archit. Sci. Rev.* **2024**, *67*, 237–254. [CrossRef]