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Systematic Review

Sustainable Reconstruction Planning from Natural Disasters (Earthquakes): A Systematic Mapping Study of Machine Learning and Technological Approaches

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Abstract

Natural disasters have various adverse effects on human lives, making it challenging for authorities to manage post-disaster situations with limited resources. Due to the extreme extent of the damage, the huge amount of resources needed to restore life to normality makes such a situation challenging. For this purpose, different methodologies have been proposed to effectively handle these types of situations. All these methodologies consider different aspects of the post-earthquake context, taking into account core parameters such as the time and cost required for reconstruction, as well as the people directly affected by the earthquake. In this paper, we conduct a Systematic Literature Review (SLR) of various state-of-the-art techniques proposed for different phases of post-earthquake situations, specifically for reconstruction planning with sustainability considerations. All these proposed solutions are differentiated on the basis of input data, parameters, and type of solutions (data sciences, civil engineering, socio-economics, and modelling). The time range chosen to filter out relevant studies is between 2000 and 2025. Eventually, we reviewed 55 related articles out of 47,539 analysed from seven different digital libraries. The findings of this SLR reveal that optimization and simulation-based approaches dominate the current research landscape, with a growing trend toward data-driven and AI-assisted reconstruction planning. However, only a few studies focus on integrating socio-economic, environmental, and physical infrastructure aspects, which represents a major research gap. These findings provide insights that can guide future researchers in designing more comprehensive frameworks to improve post-earthquake reconstruction in a sustainable manner by prioritising economic, social, and environmental infrastructures, as well as facilities for affected individuals, thereby utilising available resources more effectively.

Keywords: decision-support system; natural disaster; social benefits; physical dependencies; city reconstruction planning

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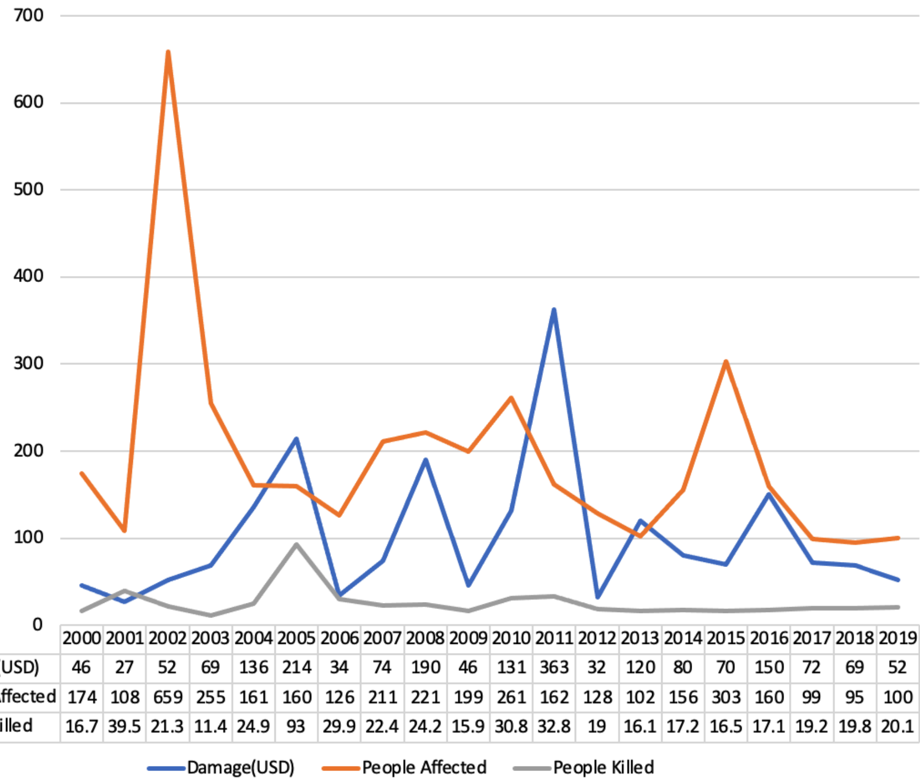
1. Introduction

In recent years, numerous natural disasters have been reported, severely affecting various locations all over the world [1]. According to an estimate, the damage cost due to natural disasters was approximately USD 67 billion per year in the last decade [2]. The ratio of economic loss due to these disasters has increased 14 times since 1950 [1]. In addition, these disasters have not only impacted the economy, but, more importantly, thousands of people have also lost their lives. From 1994 to 2003, almost 54,000 people lost their lives in different kinds of natural disasters. According to a 2003 survey, at least one person out of 25 was affected by natural disasters [3]. The United Nations Office for Disaster Risk Reduction (UNISDR) also presented a report on different types of disasters in the last two decades [4]. UNISDR statistics show that most of these disasters occur in developing countries compared to developed countries. For example, in August 2002, a drought occurred in China, while in December 2004, a tsunami affected millions of people in Indonesia, Sri Lanka, Malaysia, and nearby countries. In October 2010, a massive earthquake occurred in Pakistan, and also in May 2008, the same kind of earthquake occurred in China. Concerningly, these massive natural disasters are happening more frequently in recent years, mainly due to climate change [5].

According to the UNISDR report, among all these disasters, 44% were due to floods, 28% storms, 8% earthquakes, 6% extreme temperatures, 5% landslides, 5% droughts, 3% wildfires, 1% volcanic activities, and <1% mass movements [6]. Subsequently, the economic loss and the loss of human lives are extremely significant, as shown in Figure 1, which shows the global economic and humanitarian impact of natural disasters from the years 2000 to 2019, as by data reported in [7].



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Damage(USD)	46	27	52	69	136	214	34	74	190	46	131	363	32	120	80	70	150	72	69	52
People Affected	174	108	659	255	161	160	126	211	221	199	261	162	128	102	156	303	160	99	95	100
People Killed	16.7	39.5	21.3	11.4	24.9	93	29.9	22.4	24.2	15.9	30.8	32.8	19	16.1	17.2	16.5	17.1	19.2	19.8	20.1

Figure 1. Global statistics on the economic and humanitarian impact of natural disasters between 2000 and 2019 [8].

Recovery of damaged infrastructure in case of a natural disaster is time-consuming and costly due to the requirement of resources such as material, labour force, cost, and time, among others [9]. For example, the disaster caused by Hurricane Katrina in 2005 required five years of recovery and one billion dollars in completion costs [10]. Similarly, in the Hyogoken-Nanbu earthquake in Japan, it took 20 months only to reconstruct the highway [11]. Given the impact that natural disasters cause, authorities must make quick and efficient decisions to overcome disaster situations as soon as possible [12]. Additionally, the extended restoration time can have a significant impact on the local community, both socially and economically. For this purpose, substantial resource management is required, including budget allocation and time management. Post-disaster recovery plans have been proposed to address these challenges [13].

The post-disaster recovery plan is defined by [14] as a "*complex multidimensional long-term process that involves planning, financing, decision making, and reconstruction*". According to the United Nations Development Program (UNDP), the post-disaster recovery phase is divided into four sub-phases [15]: *relief*, *early recovery*, *recovery*, and *development*. *Relief* gives priority to saving people's lives with the help of search and rescue (SAR) operations [16]; the *early recovery* phase consists of rehabilitation of roads and identification of damage buildings [16]; *recovery* has the goal of restoring basic services and starting reconstruction of buildings including roads by considering social relationship of effected communities [16]; *development* focuses on strengthening the economy and improving quality of life [16].

Public decision-makers, including politicians, public servants, and citizens, frequently face challenges when developing a comprehensive recovery and reconstruction plan. Recovery plans must address all formal and informal requirements of the affected area as quickly as possible [17]. They must also consider the needs of the local community, the vulnerability of buildings, the budget, and the time required to complete the plan. Additionally, decision-makers should ensure that the reconstruction effort enhances the resilience of both physical infrastructure and communities by taking into account stability factors to cope with future disasters.

The post-disaster recovery (PDR) phase encompasses three key components: *goal*, *phase*, and *process* [18]. Each of these components is crucial for the long-term reconstruction of infrastructure. According to the World Bank [19], "Post Disaster Reconstruction begins with a series of decisions that must be made almost immediately. Despite the urgency of these decisions, they have long-term impacts, altering the lives of those affected by disaster for years to come." Moreover, inadequate post-disaster recovery often results in ongoing issues such as vulnerability and instability, a reality observed in many countries that have experienced disasters but failed to implement a proper recovery process [20].

While the PDR stage is critical, it still lacks a comprehensive definition that includes detailed objectives, characteristics, and content [21]. It is also known by other terms, including Post Disaster Recovery [22], Post Disaster Rebuilding [23], and Post Disaster Redevelopment [24]. Although these terminologies differ, no thorough mapping study has yet been conducted to clarify the distinctions between these concepts. Nevertheless, the ultimate aim of all these terms is to restore households, infrastructure, businesses, and government activities to their pre-disaster "normal" levels.

Despite growing research on post-disaster reconstruction, key challenges persist in the literature. Recovery planning remains a complex, multidimensional process, with inconsistent definitions and limited integration of economic, social, and infrastructure factors. Most approaches inadequately address resource constraints, lack real-world validation, and rarely connect reconstruction efforts to sustainability or resilience goals. Additionally, the fragmentation across disciplines limits comprehensive solutions. These gaps motivate our study to systematically map existing approaches those highlight post-disaster reconstruction planning in urban areas, specifically focusing on earthquakes and the application of data science methods. By "data science approaches," we refer to mathematical techniques, including operational research and optimization models, computational models, and advanced solutions such as machine learning.

The mapping study provides an overview of the current state-of-the-art solutions for these issues, detailing the proposed methods and the characteristics of the data science techniques applied to post-disaster reconstruction planning. Through this study, we aim to highlight the limitations of the existing solutions and identify current research gaps that can inform future work [25].

Given the complexity of this problem, we intend to classify the current literature on reconstruction planning techniques after natural disasters more effectively. This paper aims to uncover gaps in the research and summarize improvements across various proposed techniques to better prepare for future natural disasters.

Additionally, our goal in this mapping study is to investigate the research techniques utilized by the majority of scholars and to identify the most active areas of research in this critical field. We have addressed all the defined research questions, which is why we are conducting a systematic mapping study instead of typical secondary analyses.

This paper presents the most recent insights on post-earthquake reconstruction planning, detailing both the advantages and limitations of various proposed techniques. We believe that the findings from this mapping study will be beneficial to researchers and inspire new approaches in this crucial field. Additionally, our study aims to identify research gaps that can guide future investigations and offer innovative directions for ongoing research.

Our main contributions are as follows:

- An analysis of the state of the art that covers methodologies aimed at addressing various types of post-disaster emergencies, published over the past twenty-five years (from 2000 to 2025) across seven different digital libraries.
- A presentation of research trends within the specified time frame.
- An overview of the limitations of the selected primary studies and an identification of open issues that need to be addressed in this research area.

The remainder of the paper proceeds as follows: Section 2 presents the literature review, Section 3 presents the mapping study process, Section 4 presents the results of the systematic mapping study, Section 5 presents the discussion, Section 6 presents a potential research area, Section 7 presents a threat to validity, and Section 8 concludes the paper.

2. Related Work

Research on post-disaster reconstruction planning has gained momentum due to a series of devastating disasters in the past decade. Over time, the focus of research has evolved from merely reporting challenges to identifying key factors and patterns, and more recently, to developing theories and models through theoretical analysis and quantitative methods [1]. The reconstruction process typically involves two main components: rebuilding housing and restoring essential infrastructure such as roads, ports, electricity, railways, and water systems. In many countries, housing is treated as the top priority in post-disaster efforts, as it directly addresses the immediate needs of affected communities and is often the government's primary focus [26].

For our mapping study, we have used seven digital libraries such as IEEE Explorer, Science Direct, MDPI, ACM, Springer, Scopus, and Web of Science. Only limited studies dealt with post-disaster reconstruction planning issues. Some of the approaches from these libraries have been mentioned in this section, but have been detailed in the Appendix A. For example, Mfon et al. [27] proposed a theoretical framework for rapid post-disaster reconstruction that takes into account social, economic, and environmental factors, along with the provision of relief to affected communities. Fan et al. [28] introduced a decision-support model that combines graph convolutional neural networks with deep reinforcement learning to restore road networks in post-disaster contexts. The model is pre-trained on a range of simulated damage scenarios, enabling it to quickly generate near-optimal recovery strategies when an actual disaster occurs. An et al. [29] introduced an algorithm that integrates geographic information system (GIS) data collected through detailed surveys by the Institute of Engineering Mechanics (IEM) and the China Earthquake Administration (CEA) with Synthetic Aperture Radar (SAR) imagery to assess damage after disasters. Similarly, Doi et al. [30] developed a reconstruction planning method utilising 2D models and 3D renderings, while Mayo et al. [31] conducted a comparative analysis between the Intelligent Master Planning (IMP) approach and Conventional Master Planning (CMP). In addition, several studies have proposed formal modelling techniques aimed at optimising various aspects of the reconstruction process. Similarly, Goujon et al. [32] proposed a multi-criteria decision-making model for post-disaster reconstruction planning, utilising the Myriad tool [33] to prioritise damaged infrastructure and assess reconstruction projects based on population needs. Qiushan et al. [34] developed a post-disaster reconstruction framework focused on rebuilding residential and commercial structures, which was implemented in Dujiangyan central city. This framework emphasises the vital role of various stakeholders, such as markets, local businesses, and social institutions, in driving economic recovery by generating employment opportunities and accelerating reconstruction efforts. However, it builds on conventional methodologies and does not leverage advanced technologies like machine learning to manage post-earthquake scenarios. Moreover, the multicriteria decision making (MCDM) model introduced by Opricovic et al. [35] was designed to support the analysis and modelling of post-disaster reconstruction planning. A core strength of this model lies in its ability to identify the most suitable reconstruction alternative based on predefined input parameters such as time, cost, damage severity, and sustainability.

Based on our analysis of the existing scientific literature, to the best of our knowledge, no comprehensive review, whether in the form of a survey or a systematic mapping study, has been conducted to organise and categorise research focused specifically on post-disaster reconstruction planning [36]. Therefore, our current effort is motivated by the need and opportunity to systematically document, classify, and analyse the body of work published over the past 25 years in this domain.

3. Mapping Study Process

In this section, we describe the process we performed to carry out the systematic mapping study, following the guidelines proposed by [37].

Figure 2 summarises the overall workflow. In the figure, rounded rectangles represent *process* and grey rectangles represent *outcomes* of each process. The general workflow consisted of six steps, namely: *definition of research questions*, *conducting research*, *screening of papers*, *keywords and themes*, and *data extraction and mapping process*. Each process yields a specific outcome, which ultimately creates our mapping study.

In the following, we describe each process of the workflow and the resulting outcomes in detail.

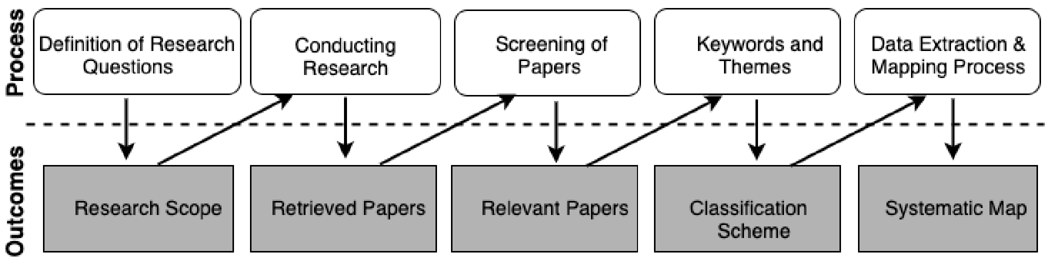


Figure 2. The systematic mapping process.

3.1. *Definition of Research Questions*

This mapping study aims to provide an overview of the research related to the adoption of AI and ML approaches to post-earthquake reconstruction. This leads us to the following research questions, formulated using the Goal-Question-Metric approach from [37].

The query we have formulated for the Goal-Question-Metric approach is the following:

Analyse the state-of-the-art post-disaster approaches **for the purpose of** infrastructure reconstruction planning **with respect to** the social benefits of affected people, politicians' role and policies, physical dependencies, time and cost for reconstruction, **to what extent** these methodologies including machine learning have been evaluated, latest active research in this domain **from the point of view of** researchers, and practitioners **in the context** of post-disaster reconstruction planning.

The main aim of this mapping study is to determine how post-disaster reconstruction has been managed using models and information technology. According to the goal of our paper, we have defined the following research questions (RQs). In presenting each RQ, we include the aim and rationale of every question we formulated:

- **RQ1:** What kind of problems have been addressed in the post-disaster management research domain?
  Aim: The aim of this RQ is to identify all issues related to post-disaster situations that have been addressed in literature.
  Rationale: In the post-disaster phase, administrators are called to develop reconstruction planning. We aim to understand the extent to which researchers have helped institutions in the reconstruction planning phase.
- **RQ2:** What approaches are used to address post-disaster reconstruction issues?
  Aim: The aim of this RQ is to focus on identifying the kind of proposed approaches e.g., Machine Learning, to handle the post-disaster situation.
  Rationale: On behalf of RQ2 we have clearly defined the criteria about the inclusion of primary studies, anything outside of these criteria will be excluded.
- **RQ3:** Which parameters of post-disaster reconstruction are mainly considered by the literature?
  Aim: Main aim of this question is to identify the key factors (such as required cost, number of affected people, or damage to buildings) mainly considered in the literature.
  Rationale: Through this RQ, we can identify key attributes used in all proposed models, and we can propose a taxonomy based on that.
- **RQ4:** What kind of limitations (i.e., threats to validity and limits) have been observed in the post-disaster reconstruction research domain?
  Aim: The aim of RQ4 is to focus on the limitation and threats to validity in proposed approaches.
  Rationale: Through this RQ, we discuss the threat to the validity of the considered primary study approach, and we can also sketch research gaps and future work.
- **RQ5:** What are the top popular venues and publication trends for the post-disaster management domain?
  Aim: The aim of this RQ is to note down all venues which are publishing articles in the computer science and social science domain related to post-disaster management. Additionally, we aim to highlight the research interest and expertise of researchers in this domain from 2000 to 2025.
  Rationale: Purpose of this RQ is to understand the venues that are publishing most of the primary studies related to the post-disaster management topic. Additionally, the rationale of this RQ is to understand the main research field (e.g., computer science, civil engineering, mathematics) of authors publishing papers in this domain. Therefore, this RQ can be divided into the following sub-RQs:
  - **RQ5.1:** What are the main publishing venues?
  - **RQ5.2:** What are the main research trends from 2000 to 2025?
  - **RQ5.3:** What are the main research fields of authors publishing in this research domain?

- **RQ6:** What are the main research gaps (i.e., open issues) in the research domain?
  Aim: This RQ describes research gaps or grey areas which have not been explored by the literature so far.
  Rationale: The rationale for this RQ is to find directions of unexplored areas for future research.

3.2. Literature Review

We apply the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach for literature identification and review [38]. Figure 3 reports the main PRISMA stages (on the left-most blue vertical columns) and the number of papers involved in each step.

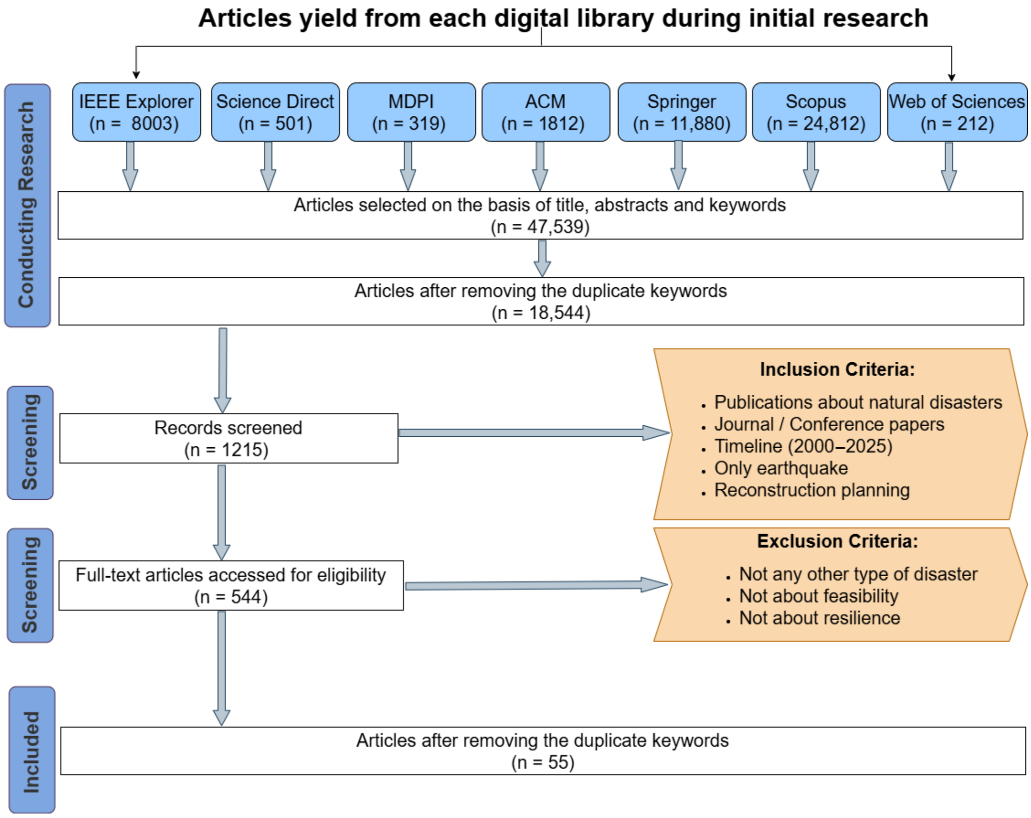


Figure 3. PRISMA flow diagram performed in our study.

The *Conducting Research* phase (see Section 3.2.1) concerns the development of research protocols by identifying the keywords and bibliographic databases to perform the search. The *Screening* phase (see Section 3.2.2) involves defining inclusion and exclusion criteria, as well as the time frame limit, for filtering the main articles. Eventually, the *Included* phase details the main articles selected after applying the screening criteria.

In the following, we detail each phase of the PRISMA workflow. This systematic review follows the PRlSMA 2020 guidelines (see Supplementary Material).

3.2.1. Conducting Research

We have used the PICOC (Population, Intervention, Comparison, Outcome, Context) [39] criteria to formulate search strings from research questions.

- **Population:** In this context, population means all those people who are directly affected due to an earthquake or a post-disaster.
- **Intervention:** Intervention is the approach that is used to solve an issue. For example, the technologies or algorithms used to handle a post-earthquake situation.

- **Comparison:** In this study, we compare different approaches from the 'Intervention' step. However, at this level, the alternative strategies are addressed from a qualitative, but not empirical, perspective.
- **Outcome:** Here we focus on factors of importance in the considered methodology like effectiveness, efficiency, or resilience of the reconstruction planning methods, which is quite worthwhile for researchers.
- **Context:** In this study, we consider works coming from both industry and academia.

To find out the most relevant studies that were published over the last 25 years (2000 to 2025), we performed an automatic search from seven selected digital libraries, namely: IEEE Explorer, https://ieeexplore.ieee.org/Xplore/home.jsp, ACM, https://dl.acm.org/, Science Direct, https://www.sciencedirect.com/, Springer Link, https://link.springer.com/, Web of Sciences, https://apps.webofknowledge.com/, Scopus, https://www.scopus.com/, and MDPI, https://www.mdpi.com/. These libraries cover most of the academic literature published. All of these databases have been selected based on the experience reported by [40].

To search for the most relevant studies, we have identified a set of keywords and related synonyms. Next, we have constructed search strings using Boolean operators (i.e., AND and OR). The full query strings are reported in Table 1.

The quasi-gold standard, as explained in the following paragraph, is employed to identify the most relevant primary studies for a specific time frame (2000 to 2025) across conferences and journals [41]. The search string consists of identified keywords that are utilized in all the databases listed in Table 1. Among the selected databases, the IEEE and ACM Digital Libraries have been chosen due to their inclusion of leading international journals and prominent conferences and workshops focusing on data sciences and disaster management. Additionally, we have included ScienceDirect and SpringerLink, as they are comprehensive digital libraries that offer extensive online scientific collections and index-based international journals. The Web of Science (WoS) is also considered, as it is one of the oldest citation indexes for the sciences and contains a collection of scholarly publishing journals, proceedings, and data compilations [42].

To broaden the scope of our research to encompass social and economic perspectives, we ran search string queries in the Scopus digital library. Its developers claim it includes works from 4000 publishers in social science fields and asserts that it is the "largest single abstract and indexing database ever built" [43]. Lastly, we have also taken into account the MDPI digital library, as it is becoming a prominent publisher in this area.

The concept of the *Quasi-Gold Standard* is outlined in [41] and is based on two key criteria: the venue (where) and the time period (when). Using these criteria, we identified relevant publications from the seven specified venues/databases, as summarised in Table 1, through a combination of automated and manual searches. Additionally, the Quasi-Gold Standard (QGS) serves as a valuable tool for assessing search strategies aimed at locating pertinent literature within a defined time frame.

With the assistance of QGS, we compiled a set of studies from related venues, including domain-specific conferences and journals, recognised for the time span from 2000 to 2025. Subsequently, we identified the top publication venues in the fields of computer science and social sciences, as detailed in Table 2.

One significant advantage of using QGS is its ability to efficiently filter relevant studies by focusing solely on the titles and abstracts of the articles. Traditional manual and automated search methods can be time-consuming when it comes to sifting through data and narrowing down publication venues; however, QGS streamlines this process considerably. After identifying relevant studies with QGS, we applied the inclusion and exclusion criteria outlined in Section 3.2.2. Ultimately, we selected 55 primary studies from the available venues.

Furthermore, we have also applied the backwards snowball technique to avoid missing any relevant primary study published from 2000 onward [44]. The backwards snowballing technique involves reviewing references cited in relevant papers, which increases the likelihood of discovering relevant studies [41]. In this whole process, we follow the guidelines of Wohlin [41].

Table 1. Search strings in databases.

Database	Search String
IEEE Explorer	("Post disaster" OR "post-disaster" OR "reconstruction planning" OR "earthquake") AND ("Housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure") NOT ("Detection" OR "rescue" OR "cyclone" OR "eruption" OR "tsunami" OR "resilience" OR "temporary" OR "feasibility" OR "authentic" OR "war" OR "flood" OR "tornado"))
ACM	("Post disaster" OR "post-disaster" OR "reconstruction planning" OR "earthquake") AND ("Housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure") AND NOT ("Detection" OR "rescue" OR "cyclone" OR "eruption" OR "tsunami" OR "resilience" OR "temporary" OR "feasibility" OR "authentic" OR "war" OR "flood" OR "tornado"))
Science Direct	("Post disaster" OR "post-disaster" OR "reconstruction planning") AND("City" OR "building" OR "road") AND NOT ("Cyclone" OR "Tsunami")
Springer Link	("Post disaster" OR "post-disaster" OR "reconstruction planning") AND ("Housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure") AND NOT ("Detection" OR "rescue" OR "cyclone" OR "eruption" OR "Tsunami" OR "resilience" OR "temporary" OR "feasibility" OR "authentic" OR "war" OR "flood" OR "tornado")
Web of Sciences	("Post disaster" OR "post-disaster" OR "reconstruction planning") AND ("Housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure") AND NOT ("Detection" OR "rescue" OR "cyclone" OR "eruption" OR "Tsunami" OR "resilience" OR "temporary" OR "feasibility" OR "authentic" OR "war" OR "flood" OR "tornado")
SCOPUS	("Post disaster" OR "post-disaster" OR "reconstruction planning" OR "earthquake") AND ("housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure") AND NOT ("detection" OR "rescue" OR "cyclone" OR "eruption" OR "tsunami" OR "resilience" OR "temporary" OR "feasibility" OR "authentic" OR "war" OR "flood" OR "tornado")
MDPI	("Post disaster" OR "post-disaster" OR "reconstruction planning" OR "earthquake") AND ("Housing" OR "city" OR "system" OR "building" OR "facilities" OR "road" OR "bridge" OR "infrastructure")

Table 2. Venues investigation during creation of Quasi-Gold standard.

Publication Venue	Subject Area	Type	Databases
ISCRAM	Computer Sciences/Social Sciences	Conf.	IEEE Explorer
CACIE	Computer Sciences/Social Sciences	Journal	Web of Sciences
Disasters	Social Sciences	Journal	ACM
ICT-DM	Computer Sciences/Social Sciences	Conf.	IEEE Explorer
RCIS	Computer Sciences/Social Sciences	Conf.	Springer

Table 2. *Cont.*

Publication Venue	Subject Area	Type	Databases
Journal of Big Data	Computer Sciences	Journal	Springer
Decision Support Systems	Computer Sciences	Journal	ScienceDir.
Advanced Engineering Informatics	Computer Sciences	Journal	ScienceDir.
ICAISC	Computer Sciences	Conf.	Web of Sci.
Expert Systems with Applications	Computer Sciences	Journal	ScienceDir.
Big Data and Society	Computer Sciences/Social Sciences	Journal	IEEE/ACM

3.2.2. Screening of Papers

In this section, we have defined inclusion and exclusion criteria for those studies which are retrieved from automated and manual searches and evaluated by two authors to decide whether these articles should be included based on their title, abstract, and keywords. For inclusion, we have applied the following criteria.

- I1: Studies which are about research methods and results of the considered research domain.
- I2: Studies must have gone under peer-review process and published in leading venues such as journals, conference proceedings, and workshop proceedings.
- I3: Studies about the earthquake.
- I4: Studies that were published from 2000 to 2025.
- I5: Studies written in English.

The studies that fall into at least one of the following exclusion criteria are excluded.

- E1: Studies that are not focused on earthquakes.
- E2: Grey literature like working papers, white and short papers, or presentations that are published in the form of some panel discussion.
- E3: Studies that are just about proposing guidelines, recommendations about disaster situations.
- E4: Secondary studies (such as mapping studies).
- E5: Studies that are not peer-reviewed.
- E6: Studies that are not written in English.
- E7: Duplicate studies which are published in different venues on various stages of their evolution.

We applied inclusion and exclusion criteria to relevant studies identified in digital libraries to determine their eligibility for our research, validating a time span from 2000 to 2025. During the full-text review, we excluded additional articles that did not meet our criteria. For the remaining articles, we employed a snowballing technique, which led us to discover five more relevant studies.

Furthermore, we ensured the reliability of the included studies for our systematic mapping by utilising Fleiss' Kappa [45]. This statistical method assesses the reliability of agreement among a fixed number of raters who classify items based on their nature. The method produces a score in binary form, where 0 indicates poor agreement and 1 indicates full agreement. Throughout this process, we enlisted the help of four independent raters to classify a random sample of 30 studies; 20 of these were already included in our mapping study, while 10 were not. The calculated Fleiss' Kappa result was 0.94, indicating a high level of agreement among the raters.

Additionally, Figure 4 illustrates the percentage of primary studies sourced from seven different digital libraries. According to the distribution, IEEE Explorer contains 38%, Science Direct 17%, MDPI 7%, ACM 19%, Springer 7%, Scopus 6%, and Web of Science 6% of the overall selected primary studies.

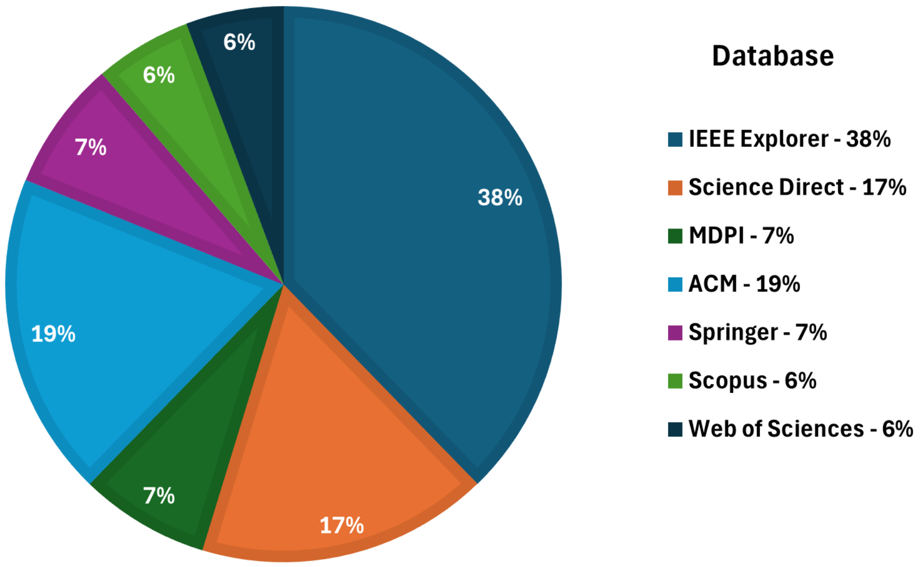


Figure 4. Primary studies percentage in each database.

3.2.3. Keywords and Themes

We have selected 55 articles after a thorough review process and applying inclusion and exclusion criteria following the PRISMA approach.

Figure 5 illustrates the proportion of primary studies sourced from each digital library. The "IEEE Xplore" has the highest number of primary studies, containing 18 articles. In comparison, the "ACM" digital library has 10 articles, while "Science Direct" includes 9 articles. The MDPI digital library has only four articles, and both "Springer Link" and "Web of Science" comprise three articles each. Scopus contributes the least, with only two relevant articles. Additionally, there are a few articles that appear in multiple libraries. For example, there are two common articles between the IEEE and ACM libraries, and Scopus shares three articles with IEEE Xplore.

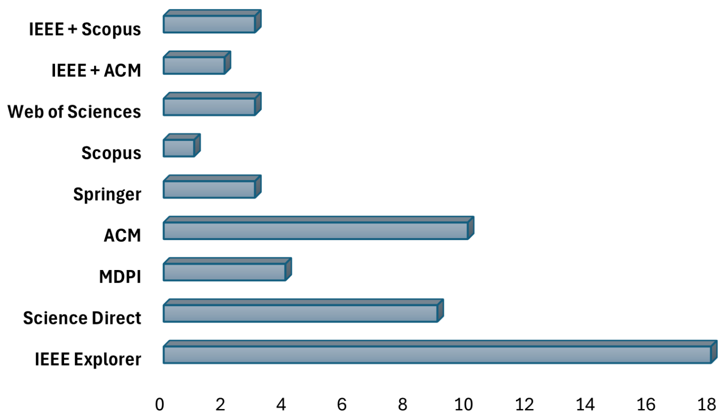


Figure 5. Selected primary studies.

Quality Assessment

After selecting a set of 55 relevant studies, we conducted a quality assessment using the most advanced quality assessment models from [46–49]. Based on the recommendations provided in these models, we developed a quality assessment checklist, which is presented in Table 3. This checklist includes six different criteria and both subjective and objective questions aimed at verifying the validity of the sources, assessing their suitability, and ensuring they are free from bias.

Table 3. Quality assessment checklist of relevant literature for mapping study.

Criteria	Questions
Producer Authority	• Is the publishing institution/platform reputable (e.g., Progress of Disaster Science)? • Is the author associated with a publishing institute? • Has the author published any other work in this field? • Does the author have expertise in this area (e.g., job title principal software engineer or expert civil engineer)?
Methodology	• Does proposed methodology have a clearly stated aim? • Is the proposed approach supported by authentic references? • Are any limitations of the proposed methodology clearly stated? • Is the proposed work based on specific research questions, and are all questions responded to effectively? • Is the proposed methodology validated by real case studies?
Scope	• Does this work relate to our mapping study domain?
Objectivity	• Is this work balanced in presentation and clearly stated? • Does the problem statement clearly state the objective? • Does this work refer to a particular vendor? • Are the conclusions of this work supported by data?
Novelty	• Does this work introduce a new idea?
Impact	• Check the impact of the considered study with respect to the following criteria. - Number of paper citations - Number of paper backlinks - Number of paper views/read

Using this checklist, we evaluated the quality of the selected literature. By applying specific selection criteria, we effectively excluded all irrelevant studies, which minimised the effort required for the quality assessment activity [50]. These criteria are based on factors such as authority of the producer, methodology, scope, objectivity, novelty, and impact. Additionally, we can utilise the same selection criteria for other research methods, such as surveys, case studies, or experiments, to further assess the quality of studies. For instance, ref. [51] proposed a quality assessment checklist specifically for case studies, which can also be applied to case studies in the formal literature.

3.2.4. Data Extraction and Mapping Process

To extract data from the selected primary studies and address the research questions defined in Section 3.1, we have created Table 4. This table includes key “Data Items” related to the research questions. According to [52], it is beneficial for one researcher to extract the data while another reviews the extraction. Therefore, we employed a two-author approach for the data extraction process. This verification by the authors is a common practice in systematic mapping studies, as noted by [39]. Our defined data extraction strategy ensures that the same criteria are applied consistently across all selected papers, including their classifications.

Analysis and Classification

The extracted information is explained and visually illustrated in Section 3.2.4. During the analysis of the study identification phase, the extracted strategies were categorised based on different search approaches, including the development of the search, evaluation processes, and criteria for inclusion and exclusion. Each of these categories was then assigned themes and sub-themes. The sub-themes were utilised in the inclusion and exclusion process (also known as a priori), which relied on strategies such as resolving disagreements between researchers to minimise bias [53,54]. Finally, the selected papers were counted according to their respective themes and sub-themes.

Data Synthesis

In the data synthesis phase, we extracted and summarized information in a meaningful manner to address the defined research questions (RQs). For this purpose, we employed various techniques for data synthesis based on the guidelines of [55] for systematic literature reviews (SLRs), along with methods for synthesising evidence in software engineering research [56]. These techniques encompass various approaches, including descriptive synthesis, quantitative synthesis, qualitative synthesis, thematic analysis, and meta-analysis. Additionally, we used a descriptive technique, as illustrated in Figure 6, to categorise the publication types (book chapters, conferences, journals, or symposiums) of the selected studies in terms of their venue. Figure 7 provides an overview of the publication ratio of the selected studies over the past two decades (2000 to 2021). Furthermore, we established a classification scheme based on topic-related keywords to effectively respond to certain research questions. These classifications are particularly useful for the mapping process.

Table 4. Data extraction.

Data Item	Value	RQ
Article ID	Integer	
Author Name	Author's name list	
Title of Articles	Name of the article	RQ1
Keyword	Keyword study indexing	RQ1
Publication Year	Calendar year	RQ5
Venue	Publication venue name	RQ5
Reconstruction	Reconstruction of buildings, infrastructure (roads, bridges), economics, education and health	RQ1
Phase	Rescue phase (to evacuate the people)	RQ1
Social Benefits	Social benefits of affected people	RQ3
Planning	Reconstruction planning of buildings	RQ1
Emergency management	Rescue and facilitate people in post-disaster situation	RQ1
Contribution type	whether this article is based on some tool, solution methodology or consist of case study	RQ2
Optimization model	Optimization model is used in proposed study	RQ2
Machine learning	Machine learning algorithm is used in the proposed study	RQ2
Mathematical model	Mathematical model is used in proposed study	RQ2
Characteristic	Which parameters are used in proposed study/algorithm	RQ3
Search Strategy	Guidelines about search strategy that which is followed to select the studies	RQ4
Visualization Type	Which technique is used to visualize the data	RQ3
Classification schemes	How were articles classified	RQ2
Search Type	Manual or automated	RQ4
Open Issues	Limitation of proposed study	RQ4
Domain Expertise	Keywords extracted from the venue description	RQ5

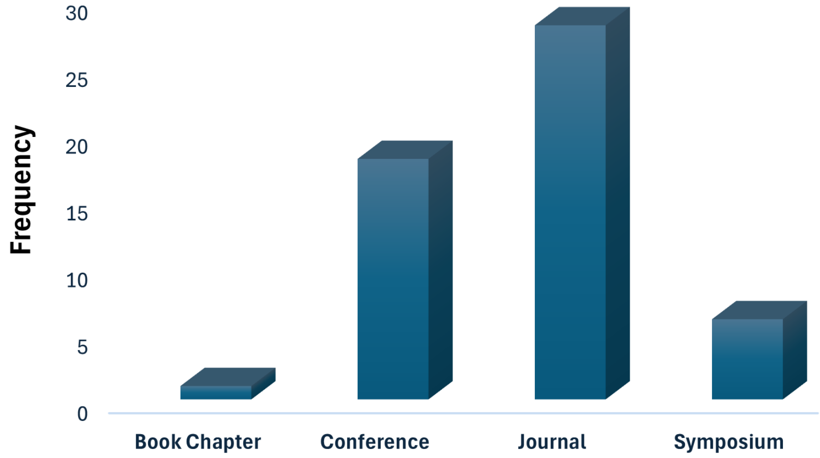


Figure 6. Distribution of selected studies with respect to publication type.

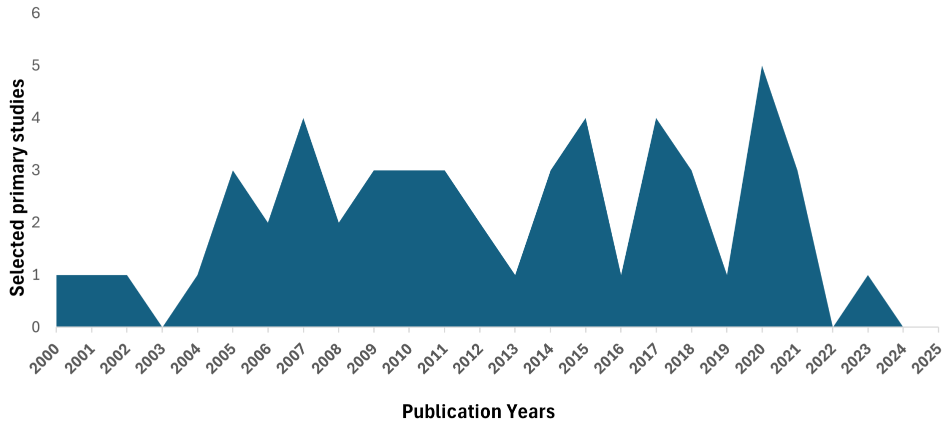


Figure 7. Distribution of selected studies with respect to time span.

4. Systematic Mapping Study Results

We conducted a mapping study in accordance with the guidelines outlined in Section 3 and our research questions. In the initial search, we identified 43 papers based on criteria such as year, country, affiliations, venue, and topic, applying our inclusion criteria. After updating our searches in line with the systematic mapping protocols [37], we discovered 10 additional papers that met the defined inclusion criteria. Ultimately, we finalised a total of 55 primary studies. A brief summary of all the studies considered can be found in Appendix A.

Figure 8 provides a detailed summary of selected primary studies from seven different digital libraries. The chart includes information about the digital libraries where these studies were published, as well as the type of solutions proposed by the authors—whether they pertain to Social & Economics, data sciences, modelling, or civil engineering (as discussed in Section 4.4). The outermost doughnut circle displays the references for the relevant primary studies.

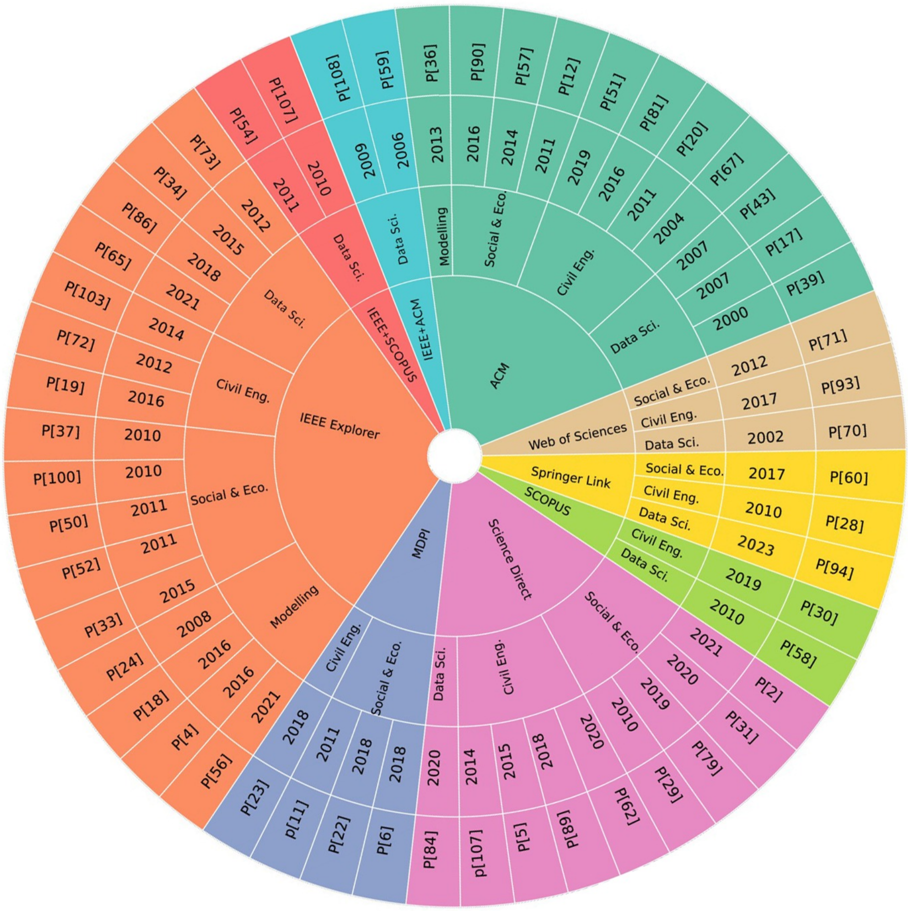


Figure 8. Distribution of publications techniques used for sentiment analysis across years.

4.1. Mapping of Primary Studies According to Publication Type

We have reviewed primary studies published across various platforms, including book chapters (1 study), conference articles (18 studies), journal articles (28 studies), and symposiums (6 studies). The contributions from these studies are illustrated in Figure 6 based on publication type. Journals emerged as the most popular publication platform, accounting for approximately 52.8% of the selected studies related to reconstruction planning in post-disaster situations. In comparison, conference articles comprised 33.9%, symposium contributions made up 11.32%, and book chapters represented the least common type, contributing around 1.88%.

Appendix B provides details on all 55 selected studies, including their publication venues, study types, research topics, the number of studies in each category, and references for the published works. These studies come from 47 different reputable venues. Specifically, there are 28 studies published in 23 different journals, 18 studies from 14 different conferences, and 6 studies from 6 different symposia, which include 1 primary study from a book chapter.

Overall, Figure 6 illustrates that all these forums are of high quality and make significant contributions to our systematic mapping.

4.2. Mapping of Primary Studies According to Publication Years

The distribution of selected studies based on publication years from 2000 to 2025 is illustrated in Figure 7. The X-axis represents the publication years, while the Y-axis indicates the number of selected primary studies.

The results show that researchers began focusing on post-disaster reconstruction planning between 2000 and 2002, utilising technical algorithms. There was little progress in 2003; however, in 2004, significant advancements were made, continuing until 2007. Following this period, there was a slight decline in research output in 2008.

In 2009, the volume of research and publications increased and remained consistent until 2011. Subsequently, a rapid decline in research activity was observed in 2013, 2015, and 2019. However, there was a swift resurgence in research in the following years, except for 2025, within the domain of post-earthquake reconstruction.

4.3. Mapping of Primary Studies According to Research Facet

For the research facet, we have used the classification scheme proposed by [57,58] to categorise primary studies according to the nature or type of research. These classifications are very simple and straightforward, as explained in the following in Table 5.

Table 5. Studies classification according to research type.

Research Type	Number of Studies
Solution Proposal	15
Solution Proposal and evaluation research	17
Solution Proposal and validation research	19
Philosophical papers	1
Opinion and Personal Experience	1

Solution Proposal: These kinds of papers propose a novel solution to the problem without a full-blown validation since these solutions are explained by proof of concept with the help of an example, a sound argument, or by some other means. We have found 15 solution proposals from selected studies.
Evaluation Research: Evaluation research is categorised as empirical research and it is based on research methods to evaluate novel solutions. All studies that are based on formal methods, such as hypothesis testing and performed experiments on real-world case studies, are considered under evaluation research. Our 17 primary studies lie in the 'solution proposal and evaluation research' category.
Validation Research: Validation research provides preliminary empirical evidence of the solution proposal that has been implemented. It is based on very deep and methodologically sound research steps to verify all relevant studies. These research steps include quasi-experiments, prototyping, mathematical analysis, and case studies, which are used to collect evidence as well as for thorough investigations. We have found 18 primary studies in this category of research type.
Philosophical Papers: According to [57], these studies are based on a new conceptual framework or a new way to look at current research. Only one primary study exists in this criteria.
Opinion Papers: These articles just describe the opinion of authors about some research area, like whether it is wrong, good, or needs improvement by using some other methods or techniques. Only one 'opinion paper' exists in our primary studies.
Personal Experience Papers: These studies are based on the author's personal experience from one or more projects. They focus more on *What* the researchers have learned rather than *Why*. These articles mostly come from industry practitioners or researchers who used to work practically on some tool and do not have discussion and methodology sections. In these type of studies, authors mention their experience in the form of a list. Thus, the evidence in these papers is often anecdotal in nature.

We can create more categories beyond the five shown in Table 5, but not all combinations would be worthwhile. For instance, a paper may propose a new technique, include validation, and conclude with a discussion section in which the author shares opinions on the work of other researchers. However, such papers do not fit neatly into defined categories. Due to these limitations, it is impossible to establish more categories [57].

The selected primary studies related to reconstruction planning in natural disasters are listed in Table 5 and have been classified into relevant categories. Almost 28.8% of the papers do not provide comprehensive validation or empirically grounded evidence, relying instead on proof of concepts. These 15 studies were classified as solution proposals. From this data, we can conclude that the relevant studies on reconstruction planning in the context of natural disasters are relatively weak in terms of scientific rigour.

The second type of primary research studies listed in Table 5 is solution proposal and evaluation research, which includes 16 studies. These studies provide high-quality evidence through experiments conducted on real case studies that assess the applicability of innovative solutions.

Validation research studies analyze the potential contribution of selected studies with respect to the experimental setup and mathematical analysis. These kinds of studies are a bit more than solution proposals because some researchers have started working in this domain in the last few years, which is why we have found 18 studies as shown in Table 5.

Currently, only one primary study is categorized under philosophical papers, as there are not many individuals proposing new conceptual frameworks in this domain.

Similarly, there is only one primary study that falls into the opinion and personal experience category.

Additionally, we employed an evaluation classification scheme from [58] to provide a more in-depth classification of selected primary studies into two categories: *real case study* and *limited experiment*, as illustrated in Table 6.

Table 6. Evaluation methods in primary studies.

Evaluation Method	Primary Studies	Total
Real Case Study *(Application of solution on real data as real context)*	PS6, PS9, PS13, PS15, PS23, PS17, PS21, PS10, PS3, PS47, PS32, PS19, PS22, PS36, PS45, PS26, PS18, PS35, PS48, PS30, PS20, PS31, PS33, PS39, PS43, PS5, PS7, PS46, PS52, PS53, PS54, PS55	32
Limited Experiment *(Application of solution unsolicited data on very simple case study)*	PS11, PS14, PS24, PS1, PS25, PS8, PS2, PS50, PS41, PS44, PS49, PS51, PS38, PS29, PS37, PS34, PS42, PS12, PS16, PS4, PS28, PS40, PS27	23

Most of the primary studies employ empirical strategies to support and evaluate their proposed techniques. However, while reviewing the selected studies, we noticed that various papers include sections titled “Case Study” or “Experiment” to validate their proposed solutions. To address this, we have categorised the selected studies into two evaluation methods.

Real Case Study: Just a research method where the researcher explores the proposed solution or topic in depth and validates on a real dataset.

Limited Experiment: Another research method where different variables are used in algorithms to test the hypothesis.

4.4. Mapping of Primary Studies According Post-Disaster Reconstruction Planning Solution Domain Facet

The mapping and classification of primary studies related to post-disaster reconstruction planning (PDRP) solutions begin immediately after data extraction. This process gathers detailed information about current research in post-earthquake reconstruction. It involves two reviewers who work through two distinct steps. In the first step, a systematic mapping is conducted. In the second step, a classification of the solution domain is created, which consists of four categories: social and economic factors, data science, modeling, and civil engineering, as shown in Table 7.

Table 7. PDRP solution facet in primary studies.

PDRP Domain	**Res. Topics**	**Primary Studies**	**Total Count**
Social and Economics	1- Social Sciences, 2- Social and Economic Experts, 3- Management Experts.	PS13, PS46, PS45, PS30, PS39, PS21, PS28, PS15, PS37, PS33, PS27, PS42, PS9, PS35, PS48, PS10, PS44, PS25,PS5	19
Data Sciences	1- Data Sciences, 2- Data Analytics, 3- Intelligent Master Planning, 4- Reinforcement Learning.	PS8, PS17, PS11, PS7, PS12, PS19, PS47, PS22, PS29, PS1, PS50, PS34, PS24, PS52, PS53, PS54	16
Modelling	1- Decision Model, 2- Modelling by Using Software, 3- Computer Aided Design, 4- 3S Planning Technique.	PS31, PS6, PS4, PS38, PS26, PS55	6
Civil Engineering	1- Structural Engineering, 2- Hydraulic Engineering, 3- Transportation infrastructure engineering, 4- Transportation System Engineer.	PS2, PS40, PS16, PS20, PS3, PS49, PS14, PS18, PS23, PS32, PS36, PS41, PS43, PS51	14

4.4.1. Solution and Economics (Social and Eco.)

These multi-disciplinary studies are grounded in economic, social, political, and 542 cultural perspectives [59].

During mapping study, we learned that some researchers have proposed social and economic studies for post-disaster reconstruction planning. The goal of all these types studies is to overcome the post-disaster situation by considering the social and economic factor. However, it is really difficult to handle such circumstances in this way, but despite this, according to Table 7 we have found 19 studies that provide social and economic solutions for post-earthquake reconstruction planning.

4.4.2. Data Sciences

These studies handle post-disaster situations by applying tools and techniques on vast volumes of data to find meaningful information for decision making [60].

In this regard, we have found 15 articles that use algorithmic techniques like genetic algorithms to handle post-earthquake reconstruction planning problems, but the overall percentage of these types of articles is 28.3% from selected studies.

4.4.3. Modelling

To solve a challenging problem, sometimes it is really difficult for researchers to use advanced algorithms or to provide a mathematical solution, and authors use modelling techniques for solution implementation. That is why we have observed during a mapping study that few authors have proposed simulation solutions but the overall percentage of these kinds of articles is much less, at is 9.4% from selected studies.

4.4.4. Civil Engineering

All these primary studies are based on professional designing and development of the infrastructure or experience papers [61]. The percentage of these kinds of articles is similar to algorithms type solutions, which is 26.4%.

4.5. Classification of Studies According to the Information Learned

According to the results, we have extracted information from different primary studies like solution proposals, empirical studies, evaluation research, philosophical papers, survey papers, and opinion papers. However, during information extraction [62], we have considered key attributes like damage level in the area, required time for reconstruction of properties, cost/budget required to reconstruct properties, and the number of people who got affected by the disaster in the damaged area. Some studies have shown information on abstract level for instance, graphs or graphical representations, which are PS28, PS46, PS33, PS31, PS26, PS1, PS31, PS38, PS4, PS48, PS15, PS39, PS25, PS27, PS44, PS46, PS30, PS21, PS42.

In this mapping we have also found empirical research articles, like PS24, PS50, PS8, PS12, PS22, PS534, PS17, PS43, PS11, PS18, PS7, PS19, PS41, PS47, PS29, PS1, PS50, PS52, PS53, PS54, PS55.

The rest of the primary studies are considered as a general category because every article contains some key attributes. All these articles are mentioned in Appendix A.

4.6. Classification of Studies According to IT Solution and Civil Engineering Field

As we go further in-depth for mapping study analysis, we have analyzed 25 papers based on IT solution and 31 papers suggesting solutions from the civil engineering field from total of 55 studies.

Additionally, the proportion of civil engineering solutions is more than IT because post-earth reconstruction problem is more oriented to the civil engineering field.

4.7. Most Fertile Researchers in Area

On behalf of primary studies, we have analyzed publications trends as well as the number of published articles by each author to check research impacts in this particular area. We have found few active researchers those have published few papers in last 25 years [63] like PS9 [35], PS25 [64], PS46 [9], PS47 [65], PS52 [66], PS53 [67], and PS55 [68]. Although the publication rate of articles increased in 2007, 2015, 2018, and then up to 2025 according to Figure 7. But, based on results and thorough analysis, we came to know that no research group deals with this critical problem by using cutting-edge technologies like machine learning.

5. Discussion

This study systematically mapped the current state of research in post-earthquake reconstruction planning from 2000 to 2025, identifying key themes, methodologies, and technological advancements. The analysis of 55 primary studies across seven digital libraries has revealed several important insights into the evolution of research and its gaps. The findings suggest that while progress has been made toward integrating optimization and decision-support models, there is still a substantial need for comprehensive frameworks that consider sustainability, socio-economic resilience, and real-world validation.

The mapping results show that data driven and AI-based approaches including optimization models, reinforcement learning, and decision frameworks are increasingly adopted, reflecting a paradigm shift from conventional civil engineering and manual planning techniques to computational and intelligent systems. However, only one study (PS52) [66] applied a reinforcement learning algorithm (DDQN) for reconstruction planning, confirming that the domain is still in its early stage of adopting machine learning for decision-making under uncertainty. This highlights a promising area for further empirical exploration and hybrid modeling.

In addition, the distribution of research types indicates that approximately 29% of the studies are solution proposals lacking empirical validation, suggesting limited methodological maturity. While 32 studies have been validated using real case data, the absence of standardized evaluation frameworks hinders cross-study comparison and reproducibility. This reinforces the need for future work to emphasize experimental validation and benchmark datasets for post-disaster reconstruction scenarios.

The parameters and attributes identified such as time, cost, damage level, sustainability, and political priority demonstrate the interdisciplinary nature of reconstruction planning, where technical, economic, and social dimensions intersect. Yet, most studies treated these parameters in isolation, neglecting their dynamic interdependencies. This fragmentation reduces the applicability of current models to complex, real world settings. A unified approach combining multi-criteria decision analysis (MCDA) with machine learning could address this limitation by optimizing trade offs among competing objectives.

Another key observation concerns the imbalanced distribution of research domains: civil engineering and social-economic studies dominate, while computational and data-science-driven methods remain underrepresented. This suggests that stronger collaboration between engineering and computer science researchers is crucial for advancing intelligent reconstruction planning. Additionally, there is a lack of work incorporating sustainability indicators and community centered design, which are essential to ensure long term resilience and equitable recovery.

6. Potential Research Areas

On the basis of the results of the mapping study, we can say that few people have tried to work but a not fair amount of research has been carried out in this domain. Most of the studies are based on a graphical representation of the damaged area instead of empirical research. That is why we can say that most research efforts are not methodologically sound and some issues remain unexplored. We have found various kinds of potential research directions especially the use of cutting-edge technologies in this critical domain of reconstruction planning in a post-earthquake situation.

Using cutting-edge technologies like machine learning in this area could be very useful because according to the results of the mapping study, we have found only one article PS52 [66] that has used the DDQN reinforcement learning algorithm for reconstruction planning apart from that which no one has used. Creating a reconstruction plan manually is a real challenge for decision makers because it is really hard for them to maintain balance in all formal and informal requirements, including a guarantee to repopulate the damaged area. Secondly, it is compulsory to consider the benefits of affected people that come from optimizing some values, e.g., the vulnerability of buildings, the budget, and time required to accomplish the building plan [69]. Development plans must be implemented according to the new strategies devised to drive future development, including taking into account the sustainability factor.

Furthermore, another aspect that public decision makers do not consider is the societal impact and relative benefits that citizens experience from the implementation of a certain recovery plan [25]. Indeed, the societal impact and benefits are different in every plan, but these are the key features that should be considered in all post-disaster phases.

For the aforementioned complexities, machine learning algorithms are the best solution that can provide a mechanism to public decision-makers, servants, and citizens that can help effectively to define and evaluate rebuilding plans.

Thus, more empirical and detailed research is required to analyze how machine learning algorithms can be used to define reconstruction plans in a post-earthquake situation.

7. Threat to Validity

There are many aspects that need to be considered when assessing systematic mapping study which can potentially limit the validity of the findings but in this section, we have discussed possible validity threats to our systematic mapping study regarding analysis, conduct, design, and clarifications. We have considered threats like bias in the selection of digital libraries, inaccuracy in data extraction, bias in the time frame for primary studies, bias in the definition of search strings, and publication bias.

Bias selection of digital libraries means we might have a distortion in statistical analysis in the selection of all those libraries which contain or do not contain too many related studies. We handled this threat (to at least some extent) by defining comprehensive inclusion and exclusion criteria for post-disaster situation-related studies.

Secondly, *inaccuracy of data extraction* and misclassifications can occur during information extraction which is done by reviewing it in a different ways. To minimize these kinds of discrepancies (to at least some extent) were solved by consensus by all reviewers.

Thirdly *bias in the time frame for primary studies* for this purpose we have considered articles from 2000 to 2025 range to mitigate chances not to miss any recent relevant study.

Fourthly to tackle *bias in search string* we have used all techniques like tabs, quotes, hyphens to exclude words and asterisk wildcard tips (at least some extent) to make a comprehensive string.

Lastly, *publication bias* refers to sometimes positive problems published more as compared to negative and also negative results take a longer time to be published and are usually cited fewer times [55]. To tackle this threat (to at least some extent), we have scanned all related journals and conferences apart from grey literature like reports or Ph.D. theses and unpublished results because all these kinds of things may affect the validity of our results.

Additionally, in this section we have also used classification schemes of [70–72]. According to these schemes, the following types of validity threats have been taken into account, which are descriptive validity, theoretical validity, internal validity, external validity, and conclusion validity. All these have explained the following.

7.1. Descriptive Validity

Descriptive validity is about the accuracy and objectivity of collected information. Usually, threats of descriptive validity exist more in qualitative studies as compared to quantitative studies. For this purpose, we have designed a data collection form to record the data related to post-earthquake situations and also describe the process of data extraction in Table 4 and have reviewed them many times, so as to not miss any related articles. Additionally, this form can be revisited whenever required for primary studies, so this threat is handled very effectively.

7.2. Theoretical Validity

Theoretical validity is about determining collected data on post-earthquake situation fits into what we have require without any bias selection. Because there is always a chance to miss some relevant studies, e.g., ref. [73] did work on two mapping studies on the same topic and ended up with different articles, we have used PRISMA [74] and backward snowball sampling techniques [75] to handle this threat in Section 3.2.

7.3. Internal Validity

Internal validity is based on two main threats, which are missing relevant studies and bias in paper selection by researchers. By the way, mapping studies consider a wide range of related articles from different databases [76]. So in our mapping study, we have considered the seven most widely used digital libraries to minimize the chance of not missing any relevant study about the post-disaster situation. We believe most of the related primary studies are considered but still, we cannot rule out the possibility that we might have missed some relevant studies during the automatic search in digital libraries. Additionally, we also used quasi-gold standard (Section 3.2) to validate the completeness of automated searches strings which are based on RQs keywords.

Researchers' bias in paper selection might also lead to inaccuracy in data extraction. For this purpose, we have defined data inclusion (DI's) criteria in Table 4 for data extraction, where all researchers were agreed, and if there was any conflict in data extraction, we settled by mutual consensus.

7.4. External Validity

According to [70], external validity of systematic mapping study is about how much findings are generalizable and useful for other population interests. So the major threat is whether considered primary studies are representing the subject area or not. For this purpose, we have followed the standard research process and considered all relevant studies apart from those which were not in English.

Additionally, some primary studies do not provide full information for extraction form. In that case, we have assumed some information on behalf of DIs during data synthesis. Similarly, some approaches did not describe drawbacks.

7.5. Conclusions Validity

Conclusion validity is about up to how much we reached on reasonable conclusion as well as the relationship between selected studies and current research trends in the considered field. To handle the first threat, we have answered all defined RQs on behalf of selected primary studies. Regarding the second threat about data extraction, classification and synthesis were performed as a team. However, still, there is a chance to miss relevant studies because qualitative-based mapping study is really difficult and can be missed in any article.

8. Conclusions

This mapping study has identified the related literature and evaluated with respect to topics, frequency of publications up to 2025, publication venues, and type of disaster.

We believe our mapping study is based on a comprehensive and state-of-the-art overview in post-earthquake reconstruction planning studies, which is quite useful for young researchers and practitioners to get an idea about this challenging field and make a contribution by using cutting-edge technologies.

We have answered all defined research questions (RQs) with the help of analysis and results on behalf of our systematic mapping study.

RQ1: *What kind of problems have been addressed in the post-disaster management research domain?*

According to our primary studies, we have considered only earthquake related studies, which are published in the last 25 years (from 2000 to 2025). After thoroughly studying, we have found 19 types of problems and all these are classified in Table 8.

Table 8. Problems addressed in primary studies.

Problems	Primary Studies
Reconstruction criteria definition	PS1, PS8, PS12, PS15, PS16, PS23, PS30, PS28, PS48
Resources management	PS3, PS14, PS21
Socio-economic policy definition	PS19, PS36, PS39, PS46, PS49
Stakeholders involvement	PS9, PS17, PS20, PS26
Data collection	PS5, PS7, PS27, PS29, PS33, PS35, PS44, PS51, PS53, PS54, PS55
Data visualization	PS4, PS40
Reconstruction planning with social aspects	PS10, PS13, PS34
Resource management	PS3, PS14, PS21
Agent-based reconstruction mechanism	PS37
Cost estimation	PS43
Data modelling	PS24
Decision making	PS25
Index-based reconstruction mechanism	PS45
Master planning	PS11
Metrics definition	PS31
Reconstruction criteria for damage roads	PS47
Reconstruction plan generation	PS52
Sustainable recovery	PS2
Temporary housing	PS22

RQ2: *What approaches are used to address post-disaster reconstruction issues?*

The approaches that we have found in primary studies to solve post-earthquake reconstruction problems are categorized into four types, which are Optimization Model (mathematical model), Decision frameworks (implemented algorithms which can mange resources, cost, time, etc. in post-disaster situation), Machine Learning, Geographical Information System, Visualization model (undirected graph or maps of damage area), and Real experience reports (studies which describe practical implementation of reconstruction plan), as shown in Table 9.

Table 9. Papers grouped based on approach.

Approaches	Primary Studies
Optimization model	PS1, PS24, PS20, PS17, PS12, PS13, PS15, PS21, PS27, PS28, PS29, PS34, PS35, PS39, PS7, PS44, PS46, PS47, PS53, PS54, PS55
Decision frameworks	PS2, PS25, PS9, PS10, PS19, PS18, PS16, PS14, PS26, PS48, PS31, PS50, PS32, PS33,PS51, PS36, PS37, PS38, PS41, PS43, PS45, PS49, PS22, PS30
Machine learning	PS52
Geographical information system	PS5, PS11, PS6
Visualization model	PS4, PS40
Real experience reports	PS3, PS8, PS23, PS42

RQ3: *Which parameters of post-disaster reconstruction are mainly considered by the literature?*

In selected studies, we had the analysis of all those attributes/input parameters that are used in proposed methodologies. We have categorised these parameters into three different tables on behalf of methodologies (algorithmic and mathematical models, visualization models, and real experience reports). Overall, 16 attributes have been noticed, which are time, cost, political priority (PP), damage level (DL), resident numbers (RN),city data (CD), physical dependencies (PD) people opinion (PO), gross domestic production (GDP), sustainability (Sustainbi.), state disaster recovery coordinator (SDRC), 3D, seismic strength (SS), stiffness, historical and cultural (H & C), and environment (Env.). Details of each primary study with respect to parameter/attributes are mentioned in Tables 10–12. Reference *(Ref)* column contains related to paper and in *input parameters* column contain parameters which are mentioned by "x" if it exists in the corresponding paper and blank space vice versa.

RQ4: *What kind of limitations (i.e., threats to validity and limits) have been observed in the post-disaster reconstruction research domain?*

According to the primary studies, our focus is on reconstruction planning of infrastructure in post-earthquake situations. After deep analysis, we have observed three types of limitations in available articles, which are Availability of updated data, Computational resources, and Model efficiency (not validated on real case studies). All primary studies have been categorised with respect to their limitations in Table 13.

Table 10. Algorithmic and mathematical models common parameter table.

Ref	Input Parameters																
PS[Ref]	Time	Cost	PP	DL	RN	CD	PD	PO	GDP	Sustainbi.	SDRC	3D	SS	Stiffness	H&C	Env.	SB
PS1	X	X	X			X			X	X	X						
PS2		X		X		X			X		X						
PS5		X						X									
PS6		X		X	X							X					
PS7		X		X													
PS9			X		X	X							X				
PS10	X	X															
PS11			X	X		X			X								
PS12		X	X		X												
PS13	X		X		X			X									
PS14				X	X	X											
PS15	X	X	X	X		X											
PS16		X	X	X							X						
PS17	X		X			X											
PS18		X		X											X		
PS19				X	X	X											
PS20	X	X	X			X		X									
PS21		X															
PS22				X	X										X		
PS24		X						X									
PS25				X		X					X						
PS26	X	X						X					X				
PS27	X			X		X								X			
PS28		X		X	X										X		
PS29		X	X	X	X					X							
PS30			X		X	X											
PS31	X	X	X	X		X			X			X	X				
PS32	X		X			X					X						
PS33		X		X		X									X		
PS34				X	X	X					X						
PS35	X	X	X			X					X						
PS36		X						X						X			
PS37				X	X			X					X				

Table 10. *Cont.*

Ref	Input Parameters																
PS[Ref]	**Time**	**Cost**	**PP**	**DL**	**RN**	**CD**	**PD**	**PO**	**GDP**	**Sustainbi.**	**SDRC**	**3D**	**SS**	**Stiffness**	**H&C**	**Env.**	**SB**
PS38		X		X					X						X		
PS39		X							X					X			
PS41	X	X								X							
PS43		X	X	X	X						X						
PS44		X	X		X											X	
PS45			X		X	X									X		
PS46		X	X		X						X						
PS47		X	X	X	X		X									X	
PS48			X	X	X	X							X				
PS49		X	X	X	X										X		
PS50		X		X	X				X							X	
PS51		X	X		X								X				
PS52	X	X	X	X	X	X	X										X
PS53	X	X		X			X										
PS54				X			X					X					
PS55							X			X						X	

Table 11. Visualization models common parameter table.

Ref	Input Parameters														
PS[Ref]	**Time**	**Cost**	**PP**	**DL**	**RN**	**CD**	**PD**	**PO**	**GDP**	**SustainbiSDRC**	**3D**	**SS**	**Stiffness**	**H&C**	**Env.**
PS4	X	X	X			X		X			X				
PS40				X		X									

Table 12. Real experience reports common parameter table.

Ref	Input Parameters															
PS[Ref]	**Time**	**Cost**	**PP**	**DL**	**RN**	**CD**	**PD**	**PO**	**GDP**	**Sustainbi.**	**SDRC**	**3D**	**SS**	**Stiffness**	**H&C**	**Env.**
PS3				X	X	X				X						
PS8	X			X		X										
PS23		X		X							X					
PS42	X			X				X								

Table 13. Papers grouped based on approaches limitations.

Limitations	**Primary Studies**
Availability of updated data	PS4, PS14, PS6, PS18, PS49, PS13, PS30, PS48, PS37, PS23, PS26, PS33, PS8, PS11, PS38, PS45, PS47, PS19, PS39, PS50, PS51, PS53, PS54, PS55
Computational resources	PS1, PS12, PS42, PS34, PS16, PS2, PS29, PS9, PS5, PS46, PS31, PS40, PS35, PS24, PS43, PS20, PS27, PS17, PS32, PS41, PS22, PS44, PS28, PS36, PS52
Model efficiency (not validated on real case studies)	PS3, PS10, PS21, PS7, PS15, PS25

RQ5: *What are the top popular venues and publication trends for the post-disaster management domain?*

During the search of primary studies, we found 11 venues that contain most of the primary studies related to the post-earthquake reconstruction domain. All those venues including research trends and expertise required are explained in the following sub-questions.

- **RQ5.1:** *What are the main publishing venues?*
  In total, we found 46 different venues on behalf of selected primary studies. Among those, only 11 conferences/journals (venues) are the most popular, which contain

more than one primary studies. These popular venues are ISCRAM, CACIE, disasters, ICT-DM, RCIS, Journal of Big Data, decision Support Systems, Advance Engineering Informatics, ICAIS, Expert Systems with Applications, and Big Data and Society as shown in Table 2.

- **RQ5.2:** *What are the main research trends from 2000 to 2025?*
  According to Figure 7, research trends vary from 2000 to 2025. In 2000, only a few people were working and then this ratio goes down in 2003, and then again in 2007 the research trend goes on top and then we can see a slight fall in 2008. Later again, the variation continues in the following years like in 2014, 2017, and 2020 research trends are on top.
  But all these studies have tried to solve the post-earthquake situation by using different techniques.
- **RQ5.3:** *What are the main research fields of authors publishing in this research domain?*
  From primary studies, we came to know that reconstruction planning is related to civil engineering, but during reconstruction, we also need to consider the social aspect of affect communities. For this purpose, the researcher needs expertise in social sciences, data sciences, and technical skills of computer science.

RQ6: *What are the main research gaps (i.e., open issues) in the research domain?*

On behalf of our results, we have observed that not many researchers are working in this research area, especially with respect to cutting-edge technologies (like artificial intelligence and machine learning). In that aspect, we have found numerous directions that can be carried out for research because the empirical research, which has already been done to handle the post-disaster situation, is not sufficient. Most of the proposed solutions in the considered studies are based on visual simulations like undirected graphs instead of empirical solutions.

We can claim that it is a great opportunity for young researchers to explore this unexplored important research fields with respect to cutting edge technologies like artificial intelligence and machine learning.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su172210035/s1, PRISMA 2020 Checklist [77].

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Data Availability Statement: No new data were created or analyzed in this study.

Conflicts of Interest: The authors declare that they have no conflict of interest.

Appendix A

In this index, we have enlisted all considered primary studies.

PS1: Ref. [35] developed a multicriteria model (the application of this model is illustrated with post-earthquake reconstruction problem in central Taiwan including restoration of the "lifeline" system) for analyzing and planning strategies for reducing social and economic cost in the natural disaster area by generating alternatives, establishing criteria, assessment of criteria weight, and application of compromise ranking method (by VIKOR).

First of all, they create alternative reconstruction plans with different scenarios and varying "system Parameters" like s1 = location, s2 = magnitude, s3 = probability s4 = number of reallocated settlements, s5 = land-use types, s6 = development regulation, s7 = fiscal policies, s8 = construction techniques. The first three parameters are determined from seismic data for the considered area and the rest of all are related to regional planning and designing alternatives. Secondly, they establish eight multicriteria (Reconstruction cost, Gross domestic production, Destroyed houses and parameters, Restoration ability, Sustainability, Acceptability by the local public, Government preferences and plans have to be evaluated on the behalf of all these criteria). The relative importance of each criteria in Multicriteria Decision Modeling (MCDM) is expressed by weight using the scaling method without losing any meaning which provides help in modeling decision making. "Equal Importance" weight (wi = 1/n) when there is no information from the decision-maker. Fuzzy logic is used for the linguistic variable (good, fair, and bad) to develop a mathematical model to implement human logic in engineering solutions. All these linguistic variables play an important role in decision-making. The fuzzy multicriteria model can treat all relevant conflicting effects and impacts in their representative units and the development of fuzzy multicriteria model is important because it deals with incomplete information. The Fuzzy multicriteria optimization (FUMCO) method is developed in this paper which has two phases CFU phase(converting fuzzy data into crisp scores) and MCO phase (multicriteria optimization using compromise ranking method). Linguistic variables converted into crispy numbers like low = 0, medium = 0.5 and high = 1 respectively. To avoid conflicts among different criteria, which is very obvious in practical problems that they have used a comparison ranking method known as VIKOR, which is introduced as an applicable technique to implement within MCDM.

PS2: Ref. [78] develop an innovative decision framework by adopting an agent-based approach for short-term redevelopment objectives and also for balancing long term goals by reducing three-dimensional vulnerabilities of communities like social, economic, and environmental ones. For this purpose, they have used residential agents, economic agents, and state disaster recovery agents (SDRC). SDRC's main purpose is to evaluate the recovery plan and prioritize the objective after every simulation through aggregated equations. The proposed approach is composed of five steps: (i) Implementation of an assessment tool to measure the three considered dimensional vulnerabilities; (ii) Modeling of stakeholders objectives, strategies, and behaviors; (iii) Data gathering to extract the information about the damage of the disaster; (iv) Simulation of the impact of the disaster event and of the interaction the stakeholders have during the post-disaster recovery phase; (v) Analysis of the simulation results. The utmost purpose of this research methodology is to provide optimal recovery strategies after disaster and policies at the community level.

PS3: Ref. [79] reviewed disaster management practices in China with an interdisciplinary analysis to check how disaster planning and management can be used efficiently in a top-down government administration system during 2008 Wenchuan Earthquake. Basically two national-level plans were drawn, one is the Overall Plan for Post-Wenchuan Earthquake Recovery and Reconstruction, and the other is the City Town System Plan for Post-Wenchuan Earthquake Recovery and Reconstruction, and the evaluation of plans contents are very helpful for policymakers to build a sustainable infrastructure.

PS4: Ref. [30] proposed a solution for reconstruction after Great East Japan Earthquake (11 March 2011). According to this solution in the start, only 2D drawings of roads and other infrastructure were collected from government offices for the construction plan which was very difficult to make consent with local residents and to start the construction plan. For this purpose, they proposed two policies to accelerate the reconstruction plan (i) Build 3D models for public shapes using CAD (Computer-Aided Design) and private shapes using CG (Computer Graphics) for better visualization and then they are integrated into the database (ii) Train human resources that can build for 3D models from 2D drawings of roads, river, rail and so on. In order to evaluate the approach, they did joint research with the city planning division of Miyako city. In meanwhile civil engineering related software was also used for 3D modeling like Infrastructure Design Suite (used for planning and visualization), Civil 3D (used for making small objects like sports facilities, parking lots), and ReMake (used for converting photo/laser scanning data into 3D mesh). As a case study in this article, they considered "Kuwagasaki" district of Miyako city. When they used city planning law data of urban planning it was difficult to use because that was in 2D and visually can't be differentiated among different tress e.g "Akinire" and "Yamaboshi" are very rare trees in Japan. For this, they have used JFP a tree generation system (written in eXtensible Plants Modeling Language) to model 3D tree shapes. The author has introduced another efficient way of 3D model of by using reconstruction by using drone came, for realistic and effective 3D models quickly, this method is much faster and efficient as compared to ordinary 3D modeling.

PS5: Ref. [80] have proposed a framework by using 3S (Special data Acquisition, Spatial Data Management, and Special Data Management) and remote sensing (RS provide different resolution remote sensing data before and after the earthquake) techniques for post-disaster reconstruction planning system (PRPSS) after Sichuan Wenchuan earthquake (China) in 2008. Both 3S (geographic information system (GIS), the remote sensing (RS) and the global positioning system (GPS)) and RS (remote sensing) techniques belong to Global Information System (GIS). Overall proposed framework (PRPSS) consisted of three layers Data Source Layer (uses spatial databases technology for the management of disaster areas spatial data), Functional Service Layer (provide primary service function related system construction), and System Application Layer (Set of planning support Analysis, provide effective support for reconstruction planning). PRPSS framework has seven types of databases which contain different kinds of disaster area data like (i) Spatial Metadata Database (describe geographic data sets content, expression, spatial reference and further it is divided into basic information and auxiliary information), (ii) The Basic Geographic Database (caries thematic data and consist of planning area 1:250,000 and 1:50,000 DLG), (iii) DEM Database (contain data which is used for 3D space visualization and 3D spatial analysis), (iv) Remote Sensing Image Database (contain different- resolution remote sensing images such as pre-earthquake and post-earthquake worldview), (v) Geological Disasters Database (contain data related to the earthquake fault zone, landslide) (vi) Social Economy Database (contain data related to the pre-earthquake population of the affected area, GDP and other data) (vii) Planning Results Database (contain plan results related to reconstruction planning). The overall system of PRPSS consisted of four subsystems (i) Spatial Data Management Subsystem (mainly used to manage and maintain databases like DEM database, social economy database), (ii) Disaster Information Extraction Subsystem (Used to extract disaster information using pre-earthquake and post-earthquake remote sensing data) (iii) Planning Support Analysis Subsystem (contain various data analysis tool related to planning business, spatial measurement, spatial data inquiry, map statistical analysis and so on) (iv) 3D Spatial Analysis Subsystem (To plan reconstruction place after analysis by 3D environment).

For the implementation of this system Tsinghua University was responsible for post-disaster reconstruction planning of Aba Tibetan that's why PRPSS constructed rapidly, ESRI's ArcSDE to manage the post-disaster reconstruction planning database. Data was provided free of cost by the State Bureau of Surveying and Mapping, The China Earthquake Administration and Beijing SPOT Company, and others unite. System developed based on component-based GIS technology. 2D GIS functions were developed by ESRI ArcGIS

Engine (ArcGIS Engine 9.3 and ArcSDE 9.3 (Esri, Redlands, CA, USA)) and 3D spatial analysis function developed by Tsinghua TS3DGIS components.

PS6: Ref. [29] say's remote sensing technology is playing an important role in collecting information on social infrastructure which is very important for relief and reconstruction after any disaster. With the increasing availability of remote sensing data, various methods have been developed for damage assessment. In this paper, authors have proposed another enriched algorithm that allows us to combine GIS data (Geographic Information System which is taken by detailed survey results from Institute of Engineering Mechanics (IEM) and China Earthquake Administration (CEA)) and SAR (Synthetic- Aperture Radar) images to estimate damage assessment after any disaster. The method was applied to PALSAR images taken over both areas Wenchuan (China) and Yushu (China) affected by the earthquake in 2008 and 2010 respectively. According to this method, GIS layer is not only applied for scale restriction but also as ancillary (non-video information such as audio data) data of structure vulnerability. As a case study author has considered the city of Dujiangyan, Sichuan, China affected by the earthquake on 12 May 2008. Two images were taken by ALOSPALSAR sensor on 5 February and 22 June 2008, respectively. And ground truth building damage data provided by the Institute of Engineering Mechanics (IEM) and China Earthquake Administration (CEA) based on the detailed survey result in GIS format.

As it is mentioned this research is related to measuring the damage of building with accuracy. For the city of Dujiangyan, GIS polygon (five damage level) of a single building contain structure and occupancy information that is accessible. But in this work, five damage levels are simplified into 3 and sorted all buildings of the study area into three types (Class A, B, and C) by applying our GIS data. By measuring the construction of similar structures building damage is more accurate way to calculate the damage. Each GIS polygon contains several kinds of information like the area of a polygon, the mean structure class of the polygon, and Z1 value of all pixels. Overall in this method GIS data participated in two steps of the whole procedure (i) In SAR intensity changes detection as a scale restriction (ii) Provide ancillary data of structure vulnerability for building damage degree estimation Anyhow still there exist a lot of issues in this methodology like GIS data is not always available; secondly, the method we applied for estimation of building damage is not workable in mountain areas as well as we can't determine moderate damage through this proposed method.

PS7: In this paper [81] have evaluated the restoration situation of a damaged building in the earthquake of 2016 (Kumamoto) in which almost 3000 buildings were completely destroyed, and it was not possible to grasp damage situation information without satellite remote sensing. Furthermore, they have used object-based and pixel-based methods for extracting detail damage of the building and other dwellings as well as to improve the resolution of a satellite image. Generally, a lot of parameters are required for image segmentation and classification by the object-based method but here damage is evaluated by the optical and SAR images observed immediately after the disaster investigated and a lot of damage features of building was investigated by the field surveying. In this paper they have taken Mashiki town as a case study (severe damage in Kumamoto earthquake) for evaluation of proposed methodology, using high-resolution satellite data one year after the earthquake.

PS8: In this paper [82] have discussed the reconstruction approach after the Wenchuan County earthquake in 2008 of Sichuan Province. After three years of post-disaster reconstruction in the disaster area economy, ecology, environment has been fully restored (all this information was collected from the Department of Tourism in Shuimo town). Though achieving such a heavy construction in just three years have shocked the world, on the behalf of this amazing achievement Shami Town in Wecnhuan County was awarded as

"Global Best Example Post-Disaster Reconstruction". From studying and discussing the reconstruction model they found that the town used regional advantages, improved infrastructure, explore tourism resources, changed the economic growth mode, and focused on the protection of historical and cultural. Basically, for the whole construction, they have adopted "Partner Assistance" approach, on the other hand, Shuimo town has traditional culture and historical context which is based on two regions "Chanshou Old Street" and "Qiang city in Shuimo town" as well as it contains natural scenery. In this way tourism industry is the support strength of the national economy. In overall reconstruction, they have adopted the following strategies (i) They have repair old buildings according to their old style, size, and features so they can revive the old style and strengthen the modern technology of resisting the earthquake. (ii) Some buildings which didn't collapse in a disaster such as old houses or shops, left their appearance from outside as it is but inner side structure equipped with modern structure equipment to resist the earthquake up to 9.0 magnitude. (iii) Some buildings did not collapse but their location hampered the design of the city, so they decided to push them down and reconstruct. (iv) Keeping original structure as it is but they brought some other styles of architecture to diversify Qiang Zhai tourism product.

After all state of art post-reconstruction but still, author have few suggestion (i) Secondary disasters caused by an earthquake like debris flow, collapse, landslide have greatly hampered the need to avoid quality reconstruction. (ii) At present, the tourism benefit in shumio town has not shown itself completely. They need to have further refinement about many aspects such as traveling website construction, advertising, the quality of reception etc. (iii) Extend the tourism industrial chain and develop the economy with three-dimensional development direction such as Qiang minority culture, tourism industrial chain.

PS9: Ref. [26] describe the role of key stakeholders in project management during post-disaster reconstruction like project financing and design to start the reconstruction. Additionally, they have identified key challenges during post-disaster reconstruction like policies, construction budget/cost, labour cost, coordination, communication, and political environment. In the end, they have explained 10 critical success factors that must be taken into account during post-disaster reconstruction which are: effective institutional arrangement, coordination and collaboration, supportive laws and regulations, effective information management system, competencies of managers and team members, effective consultation with key stakeholders and target beneficiaries, effective communication mechanism, clearly defined goals and commitments by key stakeholders, effective logistic management and sufficient mobilization and disbursement of a resource.

PS10: In this paper author's [83] have proposed a mechanism for the post-earthquake reconstruction of the building to take care of the environment (like natural environment, social environment, economic and cultural environment) and fulfill basic requirements like reconstruction of sites, the planning system, local culture, building, and environment design, physiological reconstructions and establish a good social and cultural environment to improve peoples quality of life. At last, the authors have validated the approach on Wenchuan earthquake reconstruction planning.

PS11: In this paper [31] did a comparative analysis of Conventional Master Planning (CMP) practices with the Intelligent Master Planning (IMP) approach (By using a case study of a massive earthquake on 8 October 2005 in Azad Jammu and Kashmir leaving more than three millions people homeless). As most developed countries don't have any mechanism to tackle these kinds of massive disasters. So after successful relief operation government has started work of reconstruction and rehabilitation. So master plan project was assigned to the University of Engineering and Technology Lahore, it was a great challenge because the need of the people was very urgent, and the contemporary planning process was consuming, that's why study required efficient planning groups data collection, and analysis. The new planning approach has been named as "Intelligent Master Planning for Disaster Afflicted Area' and it heavily relied on state-of-the-art remote sensing and GIS technologies, including the use of computer-based data sheets and analytical tools such as MS Excel 2003 ((Microsoft Corporation, Redmond, WA, USA)) and IBM SPSS Statistics 16.0 (IBM Corporation, Armonk, NY, USA) for statistical analysis. They have used 14 different assessment criteria (Time Saving, Effective in disaster afflicted difficult areas, Resource mobilization at the start of a project, Involvement of manpower resources, Maps updating and reproduction, Statistical and analytically choices and opportunities, Spatial data analysis, and thematic maps production, Graphics, and illustrative capabilities, Data transfer-ability, Periodic revision of plan and updating facility, Quick and rational decision-making abilities, Degree of public participation, Spatial and statistical data coverage, Conformity and adaptability with the cutting-edge technologies) on the behalf of all those criteria IMP proved more advantages then CMP. Therefore study propose the adoption of IMP as a modular approach, time-efficient, intelligent, detailed, and disaster sensitive.

PS12: In this paper authors [32] propose a generic decision support model dealing with various sectors (education, housing, and health) that could need after disaster applied through software module to automatically assign a priority value to sets of reconstruction projects in a post-disaster phase. Basically, this article covers damage areas and the priority of reconstruction projects. The objective is to support the decision-makers that are not experts in post-disaster management and that have to take complex decisions related to many parameters: evolution of the disaster effects, population needs in different vital sectors, etc. Multi-Criteria Decision Making process is basically decomposed into Modeling Phase (to construct a decision model that captures the decision-maker preferences) and Exploitation Phase(corresponding to define the priority). They have developed a tool by using Myriad (Multi-Criteria decision tool which contains two sets of criteria weight and interaction and each criteria is evaluated with the value between 0(bad) and 1(good)) which is based on post-disaster methodologies characteristics and consider only high priority sectors like housings, health, education, transportation, energy, water, food, and entertainment. The module first evaluates the relevance of each reconstruction project, and next evaluates the relevance of sets of reconstruction projects taking into account the context and the population needs. It implicitly represents synergies among projects. This approach is implemented in the Destriero project demonstrator to support the prioritization of the reconstruction project after a combination of disasters near Madrid.

PS13: In this paper authors [78] have described that natural disasters affect the built environment's infrastructure and disturb the economic sector's sustainability and welfare. This requires a disaster recovery decision support tool that capitalizes on the redevelopment opportunities to elevate societies to a more-sustainable and less-vulnerable status. As such, this paper presents an agent-based model approach that aims to meet the objectives of stakeholders while decreasing the community's economic vulnerability. Agent behavior considered three assumptions which are Agents are interdependent, Agents follow simple rules, Agents are adaptive. Proposed agent-based model represents the residents of the impacted community, the economic sector, insurance companies, and disaster recovery plans. In addition, the model presents Local Disaster Recovery Management (LDRM), State Disaster Recovery Coordinator (SDRC), and Federal Disaster Recovery Coordinator (FDRC). Accordingly, the proposed model adopts a five-step research methodology: (1) implementing a comprehensive economic vulnerability assessment tool; (2) developing the objective functions and learning algorithms of the associated stakeholders; (3) modeling the different attributes and potential strategies of the various stakeholders; (4) creating an interdependent agent-based model that simulates the aforementioned information; and (5) interpreting and analyzing the results generated from the developed model. The model is developed and tested on the post-Katrina residential housing and economic-financial recovery in three Mississippi coastal counties. The model proposed an evolving optimal budget distribution that decreased the economic vulnerability and increased the residential and economic recovery. Ultimately, the holistic framework utilized in this study lays down the foundation for a new generation of interdisciplinary managerial decision-making support tools.

PS14: Ref. [84] proposes theoretical model for post-disaster planning using regional and local level plans. The suggested model consists of three phases which are enabling phase, reconstruction planning phase, and reconstruction implementation phase. The main focus of this proposed framework is to make effective management during post-disaster housing reconstruction.

PS15: In this paper [32] proposed a multi-criteria decision model to take a complex decision in a post-disaster situation to reconstruct the damaged area by considering several parameters like damage level in the affected area (number of damaged houses, schools, hospitals, and transportation), the interconnection between damage buildings and to prioritize reconstruction projects. They have validated this model on fictive examples but later they will do it evaluation on real data.

PS16: Ref. [85] describe the overall government reconstruction plan after a massive earthquake in Wenchuan in western China. In this reconstruction strategy's poverty of affected people is the main attribute due to this they have given priority to settle rural areas first to facilitate poor people. According to research although some resources were not used for the poor population because resources were allocated on behalf of damage assessment.

PS17: Ref. [86] have described about community participation in reconstruction planning. According to this approach "where", "why" and "how" users can be involved in the technical design process and decision making where their contribution leads to positive results and outcomes. Ref. [86] have validated this approach on four different post-disaster housing reconstruction projects: one in Colombia, one in El Salvador, and two in Turkey.

PS18: Ref. [34] describes post-disaster housing reconstruction mechanism and policy implementation in Dujiangyan central city. In this model, multiple entities (like market and social institutions) played a vital role in the economic and early completion of buildings reconstruction. But this paper is just elaborating on conventional methods not taking into account cutting-edge technologies to handle the post-disaster situation.

PS19: Ref. [87] describe socio-economic and spatial polarisation framework which is used to recover damaged houses including reconstruction policy which has been defined after Great Hanshin Earthquake in Japan. In this framework, two-tier policy is introduced one is self-help group like people can reconstruct their own houses at market price and the second one is public housing or residential welfare housing directly provided to poor and needy people after reconstruction.

PS20: Ref. [88] present social capital role in post-disaster rehabilitation and reconstruction. According to this model people actively participate and deeply involved in reconstruction programs to make a successful and speedy recovery. Additionally, in this reconstruction model, people have the highest satisfaction rate as well rehabilitation speed. This model is successfully validated in Kobe (Japan) and Gujarat (India) earthquakes.

PS21: Ref. [89] proposed a framework for managing resources during post-disaster situations including stakeholders need, legislation and policy for reconstruction, the capacity of the construction industry to rebuild the buildings, enhance the capacity of a transportation network, and incorporating environmental considerations to reconstruct damaged infrastructure and buildings. According to authors [89] main motivation behind this framework is the post-Wenchuan earthquake reconstruction process because they have faced a bottleneck to manage resources.

PS22: Ref. [90] proposes a framework for strategic planning to make temporary houses in a post-disaster situation by considering physical, social, economic, and organizational aspects. For analysis of this framework, six case studies have been considered for temporary housing which is Greece in 1986, Turkey and Colombia in 1999, Japan in 1995, Mexico in 1985, and Italy in 1976.

PS23: Ref. [91] describes owner-driven reconstruction approach after 2005 Kashmir and 2013 Awaran earthquakes in Pakistan. This approach is based on private housing and become very successful for safe housing and to complete reconstruction in time. But still, there was a delay in some buildings because of participation of different agencies and took time in decision-making and coordination about the reconstruction process.

PS24: Ref. [92] proposed methodology by using Unmanned Aerial Vehicles (UAV) for 3D modeling of damage or collapsed buildings for reconstruction. In this method, they have used commercial and open-source tools for 3D modeling and computational time is very fast depending upon the number of damaged infrastructure.

PS25: Ref. [64] have used the entropy method for posy-disaster decision making in the proposed framework to define prioritization strategy about damaged bridges or buildings on behalf of available data. They applied the proposed framework to Nisqually earthquake.

PS26: According to [93] post-disaster reconstruction process after 5.12 Wenchuan earthquake was really difficult, complex, and time taking. In their research, they took public opinions during the reconstruction process to consider their social benefits.

PS27: Ref. [94] introduced a framework where they have proposed the use of collaborative photogrammetry to involve disaster-affected people during the planning and reconstruction process. They have validated this approach in sample small data set by a group of citizen-scientists after the 2016 Central Italy earthquake.

PS28: Ref. [95] have proposed an optimization model by using Bean Optimization Algorithm (BOA) based on fuzzy preference relation. According to this model in a post-disaster situation reconstruction of public services will get priority. The proposed model is validated post-earthquake reconstruction in China.

PS29: Ref. [80] proposed framework called post-disaster reconstruction planning supporting system (PRPSS) to reconstruct damaged buildings supporting system by using 3S technique planning for information extraction of the damaged area, assessment of damage cost, reconstruction planning, and so on.

PS30: Ref. [96] proposed an innovative polynomial-time online algorithm for road reconstruction in a post-disaster situation because roads play a vital role to evacuate people and reconstructing damaged buildings. Additionally, they [96] have checked the performance of the proposed algorithm with others on Istanbul road network and show its performance is much superior to others.

PS31: Ref. [97] have proposed reinforcement measures and suggestions during post-disaster reconstruction after the M8.1 earthquake happened near Pokhara, Nepal. They have used finite element software for reconstruction modeling. Additionally, they have considered transmission path of structure, stiffness, consistency of structure, and site selection.

PS32: Ref. [98] proposed a BIM-based post-disaster reconstruction framework called Virtual Permitting Framework (VPF) to improve the quality and to recover damage assets. VPF consisted of five components which are: (i) Buildings inspection and damage assessment (ii) classification of damages into different groups (iii) database of damaged buildings (storage) (iv) reconstruction type with local state regulation (v) virtual permitting

(vi) decision about approval/rejection of construction unit. The proposed framework was successfully validated on the city of Gainesville data set.

PS33: Ref. [99] present a methodical framework for effective management and for reconstruction of buildings in post-disaster situation. Key attributes in the proposed framework are effective management during reconstruction, consideration of affected communities, and involvement of all key stakeholders to take input for the reconstruction plan.

PS34: Ref. [83] present an approach for residential environment planning by considering reconstruction site, planning of the system, maintaining local culture, building design, psychological reconstruction, and keeping intact social and cultural environment for establishing a good quality of life of local residents.

PS35: Ref. [100] present an approach that is based on a collection of information like the design before reconstruction, required stiffness of walls which is increased by using cement, technical regulation for reconstruction are considered.

PS36: Ref. [82] have described the "hematopoietic type" post-disaster reconstruction model which is used in Wenchuan County in Longmen mountain of Sichuan province. In this model, key attributes are infrastructure improvement, education, environment. economic growth, and protection of historical and cultural aspects.

PS37: Ref. [101] present CM-agent model approach is used to solve construction management problem in post-disaster situation. Additionally, this model has the capability to work on "sound and rapid" (without any influence of other stakeholders) construction requirements, can solve public project management problems, and to make ensure the execution of public projects successfully in post-disaster reconstruction.

PS38: The approach proposed by [102] for post-disaster reconstruction in Lueyang county based on analyses of rebuilding houses layout and reconstructing low-cost and affordable houses on a priority basis.

PS39: Ref. [103] present an approach that gives the accurate design of rural housing reconstruction with respect to a lifestyle of residential users. Additionally, housing reconstruction becomes a source of economic revelry including ecological and energy-saving technique for making an economical residence.

PS40: Ref. [30] proposed an approach to speed up reconstruction in at Sanriku coast areas that were affected by Great East Japan Earthquake. They have followed two policies in this model, first one is 3D model to visualize reconstruction plans and the second one is to train the local people that can build 3D models for reconstruction plans by considering all basic entities s like roads, bridges, railways, and buildings.

PS41: Ref. [81] have proposed an approach to reconstruct damaged buildings after one year of 2016 Kumamoto earthquake after gathering information with the help of high-resolution satellite data of Worldview-3. They have used Gray-Level Co-occurrence Matrix (GLCM) for calculation of texture index, and analysis shows there is too much difference with respect to building damage level and recovery situation.

PS42: Ref. [79] reviews post-disaster management strategies for the analysis and management by using a top-down approach after 2008 Wenchuan Earthquake. For this purpose, they have used two different plans which are "Overall Plan for Post-Wenchuan Earthquake Recovery" and "Reconstruction and the City/I-own System Plan for Post-Wenchuan Earthquake Recovery and Reconstruction" by considering different strategies to make reconstruction plan on behalf of available resources and funds.

PS43: Ref. [104] proposed an approach for reconstruction of roads including estimation of repairing cost on behalf of total damage area in a post-disaster situation. In this approach, they also consider bridges, tunnels, and pavements as a part of roads reconstruction. Additionally, they [104] also describe rehabilitation duration for reconstruction with cost.

PS44: Ref. [105] proposed framework for post-earthquake reconstruction which claims proper institutional arrangements can make reconstruction and recovery process fast. They justified their claim with Weizhou Town reconstruction which is consisted of both long-term and short-term reconstruction of a public building with public facilities. Additionally, this approach is a much better top-down approach and rapid reconstruction process.

PS45: Ref. [106] proposed a mechanism for post-disaster reconstruction based on index system to restore the living and to reconstruct damaged buildings and other facilities. They [106] have used the quintile grading method to improve the accuracy of the model by using DIDF method. Validation of this approach is done by empirical analysis of China's 31 provinces.

PS46: Ref. [9] proposed a post-disaster recovery model to define the priority of reconstruction plans of damage projects/facilities on behalf of socioeconomic factors of affected communities with minimum time and cost. They have used AHP (Analytical Hierarchy Process) for decision making, and an optimization model for resource allocation. For evaluation, they have applied this model on counties (called parishes) data. In [9] they didn't consider damage physical dependencies among reconstruction units and their priority to reconstruct but our model explicitly considering.

PS47: Ref. [65] proposed a model for the reconstruction of roads and removing debris in a post-disaster situation. They have used two-stage methodology Steiner Tree Model (to check roads that need to be reconstructed first) and Scheduling Algorithm (Scheduling for restoring roads and crews assignment). For verification, they applied this technique on 1994 Northridge California Earthquake data.

PS48: Ref. [107] proposed an innovative approach for the dynamic evolution of disasters to assess post-damage facilities to help planners for making the right decision on behalf of available information. They have used web-based technologies for collection and analysis of damage territory data. For validation of this approach, they have used Tacloban city data in the Philippines which was affected by Super Typhoon Haiyan in November 2013.

PS49: Ref. [108] present an approach to prioritize damage facilities on behalf of social and economic benefits including resource allocation for reconstruction in a post-disaster situation. They have validated this model with the help of different tools like Federal Emergency Management Agency and GIS.

PS50: Ref. [109] proposed a framework for post-disaster reconstruction called "Building Back Better" which considers five different attributes before starting reconstruction of any damaged unit. Those attributes are financial/economic, social, organizational, and environmental.

PS51: Ref. [110] proposed an approach for reconstruction planning which is consisted of four steps: (i) use agile approach for planning and implementation (ii) specific time for gaining community trust (iii) usage of technologies, expert labor and quality material for hazard-safety housing (iv) capacity building of community until reconstruction work complete. Authors have validated this approach [110] on four different case studies.

PS52: Ref. [66] proposed an approach for post-earthquake reconstruction planning by using DDQN reinforcement learning algorithm. In this approach, they have considered all compulsory attributes like social benefits of affected people, political priority, time, and cost to reconstruct damaged buildings and roads. They have validated the approach by applying it to L'Aquila city which was affected by the earthquake in 2009.

PS53: Ref. [67] proposed an approach in which they presents a robotic crane system using Proximal Policy Optimization (PPO), a reinforcement learning algorithm, to automate construction material transport after earthquakes. Two models are trained—one with obstacle awareness and one without—and tested in simulated tasks. The obstacle-aware model outperforms the other in safety, efficiency, and path planning. While effective in simulations, further validation in real-world scenarios and comparison with other RL methods are needed.

PS54: Ref. [111] proposed an approach which explores how suburban communities can recover from floods more effectively, focusing on Kogi State, Nigeria. By comparing cases from India and France, it identifies poor land use, weak building codes, and limited planning as major challenges. The authors highlight practical solutions such as elevated housing, better drainage systems, and sustainable land-use practices. They stress that rebuilding after floods should not only restore homes but also improve resilience and sustainability. The paper concludes that integrating disaster risk management and sustainable design can help achieve safer, more resilient communities.

PS55: Ref. [68] proposed study examines how well post-disaster recovery and long-term development were coordinated after the 2008 Wenchuan earthquake in China. Using spatial and statistical analysis, the authors assess changes in the social, economic, and ecological systems from 2009 to 2018. Results show that while recovery has improved overall, progress remains uneven across regions. Some counties advanced quickly, while others lagged behind due to resource and policy differences. The paper introduces a predictive model to forecast recovery effectiveness and guide future reconstruction efforts. It highlights the importance of balanced regional development, sustainable planning, and government support to maintain long-term resilience in disaster-affected areas.

Appendix B

Table A1. Primary studies distribution according to publication resources.

Pub. Venue	Type	Res. Topic	No	Ref
Computer-Aided civil and infrastructure engineering	Journal	Reconstruction Modelling by using Software	1	PS1 [35]
SIGSPATIAL International Conference on Advances in Geographic	Conference	Entropy method	1	PS25 [64]
International Conference on Research Challenges in Information Science	Conference	Reinforcement Learning	1	PS52 [66]
Disasters, Crisis, Hazards, Emergencies and Sustainable Development	Journal	Management Experts	1	PS14 [84]
International Conference on Mechanic Automation and Control Engineering	Conference	Civil Engineer	1	PS35 [100]
International journal of disaster risk reduction	Journal	Data Sciences	1	PS48 [107]
Journal of Infrastructure Systems	Journal	Agent Technology	1	PS2 [78]
International Journal of Disaster Risk Science	Journal	Data Analytics	1	PS3 [79]
International Conference on Network-Based Information Systems (NBiS)	Conference	Computer Aided Design	1	PS4 [30]
IEEE International Geoscience and Remote Sensing Symposium	Symposium	Global Information System	1	PS5 [80]
International Geoscience and Remote Sensing Symposium	Symposium	Geographic Information System	1	PS6 [29]

Table A1. *Cont.*

Pub. Venue	Type	Res. Topic	No	Ref
IEEE International Geo science and Remote Sensing Symposium	Symposium	Pixel-based method	1	PS7 [81]
International Conference on Management Science and Engineering	Conference	Social Sciences	1	PS8 [82]
International Conference on Information Systems for Crisis Response and Management	Conference	Social Sciences Discrete Analysis Social Sciences	3	PS10 [83], PS45 [106], PS34 [83]
International Conference on Advances in Space Technologies	Conference	Intelligent Master Planning	1	PS11 [31]
International Conference on Information and Communication Technologies for Disaster Management	Conference	Myriad Experts	1	PS12 [32]
International Journal of Disaster Risk Reduction	Journal	Data Sciences	1	PS32 [98]
International CIPA Symposium	Symposium	Photogrammetry	1	PS27 [94]
Nepal Engineer's Association Technical Journal	Journal	Social Sciences	1	PS23 [91]
International Conference on Network-Based Information Systems	Conference	Modelling by using software	1	PS40 [30]
IEEE International Geo science and Remote Sensing Symposium	Symposium	Gray-Level Co-occurrence Matrix	1	PS41 [81]
Practical Action Publishing	Book Chapter	Social and Economic Experts	1	PS50 [109]
Applied Mechanics and Materials	Journal	Social Sciences	1	PS26 [93]
Procedia engineering	Journal	Management Experts	1	PS33 [99]
International Conference on Management Science and Engineering	Conference	Data Sciences	1	PS36 [82]
Transportation Research Part B: Methodological	Journal	Transportation Research	1	PS30 [96]
Structures	Journal	Reconstruction Modelling by using Software	1	PS31 [97]
International Journal of Disaster Risk Science	Journal	Social and Economic Experts	1	PS42 [79]
International Journal of Transportation Engineering	Journal	Social and Economic Experts	1	PS43 [104]
Journal of Management in Engineering	Journal	Analytical Hierarchy Process	1	PS46 [9]
Applied Mechanics and Materials	Journal	Social Sciences	1	PS9 [26]
Journal of infrastructure systems	Journal	Agent Technology	1	PS13 [78]
Applied Geography	Journal	Social Sciences	1	PS16 [85]
Habitat international	Journal	Social Sciences, Social and Economic Experts	2	PS17 [86], PS44 [105]
Progress in Disaster Science	Journal	Social and Economic Experts	1	PS18 [34] describes
Housing Studies	Journal	Social and Economic Experts	1	PS19 [87]
International Journal of Mass Emergencies and Disasters	Journal	Social and Economic Experts	1	PS20 [88]
Disasters	Journal	Management experts, Social and Economic Experts	2	PS21 [89], PS22 [90]
Multimedia tools and applications	Journal	Unmanned Aerial Vehicles	1	PS24 [92]
International Conference on Computer Sciences and Convergence Information Technology	Conference	Data Analytics	1	PS38 [102]

Table A1. *Cont.*

Pub. Venue	Type	Res. Topic	No	Ref
International Conference on Electric Technology and Civil Engineering	Conference	Social and Economic Experts	1	PS39 [103]
Operations Research	Journal	Steiner Tree Model and Scheduling Algorithm	1	PS47 [65]
International Conference on Logistics Systems and Intelligent Management	Conference	Agent Technology	1	PS37 [101]
International Journal of Project Management	Journal	Data Sciences	1	PS51 [110]
IEEE Youth conference on information, computing and telecommunications	Conference	Fuzzy Relations	1	PS28 [95]
IEEE International Geo science and Remote Sensing Symposium	Symposium	3S Planning Technique	1	PS29 [80]
International Conference on Information and Communication Technologies for Disaster Management	Conference	Decision Model	1	PS15 [32]
Computing in Civil Engineering 2019: Smart Cities, Sustainability, and Resilience	Conference	Modelling by using software	1	PS49 [108]
Pacific Conference on Earthquake Engineering 2023	Conference	Data Science	1	PS53 [67]
American Journal of Environment 1594 and Climate (AJEC) 2025	Journal	Decision Model	1	PS54 [111]
Land 2025	Journal	Data Science	1	PS55 [68]

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