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Systematic review of critical factors affecting post-earthquake infrastructure recovery

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ABSTRACT

The infrastructure recovery process contains an array of influencing factors that dictate the pace, quality and cost of recovery, which are areas of core interest to government decision makers, utility providers, and business sectors. The purpose of this research is to better understand how this process is influenced by internal and external factors that can slow or speed up infrastructure recovery after a damaging natural event. A systematic review was undertaken to explore literature from domestic and international case studies and comprehensively review the nature of these critical factors and their impact upon the reconstruction process. The findings from this research will advance the understanding of the interdependencies between factors and presenting different cases on how these factors were accommodated in different reconstruction settings. This project will develop the core knowledge of affected stakeholders on the disaster reconstruction process by providing insight into the challenges that are faced in infrastructure recovery in order to ensure there is greater readiness for future events and appreciation of the hurdles involved.

Keywords: Infrastructure utilities, downtime, earthquakes, recovery, impeding factor, systematic review

INTRODUCTION

Naturally occurring damaging events are becoming more prevalent and damaging as societies continue to develop and inhabit disaster prone areas [1]. The modification and adaption of environments exasperates such vulnerabilities. Infrastructure, created to support the inhabitation of people is prone extensive damage and disruption from a range of events including as seismic, meteorological volcanic occurrences and climatic change [2]. While infrastructure is regularly constructed with rigidity to withstand design-level events, there is regularly a degree of damage that takes place requiring remediation and repairs [3]. The extent of repair can range from minor cosmetic damage to destruction leading to the demolition and the reinstatement of new infrastructure.

Previous events highlight that the route to recovery of infrastructure is very broad, defined by the measures put in place by the acting governments and municipalities [4]. There are a multitude of factors that influence the recovery process from the early stages of response through to the closing actions of reconstruction [5]. An awareness of these factors is of vital importance for all stakeholders in order accommodate and action a suitable response to minimise the disruption.

The time for restoring the damaged built environment after a major earthquake is a critical issue in the study of urban reconstruction following the impact of disasters[6]. An earlier study investigated the critical elements (i.e. decisions, mechanisms, processes and factors) that affect the reconstruction time in Christchurch following the 2010/11 Canterbury earthquakes [7]. The study considered the recovery process to follow a stepped progression through

Inspection and Assessment, Decision Making, Financing, Adjustment (Reconstruction capacity and capability) and finally Construction.

This paper provides a summary of the systematic review of the literature that was undertaken to synthesise the exposure of the initial list of critical variables from studies to date and to identify further critical elements from the existing body of knowledge. It aims to comprehensively identify the critical factors of the infrastructure reconstruction process and to provide a brief of the forms of the encounters within each factor. Due to the extensive range of sources, a systematic review of literature is the only way to comprehensively capture the critical variables raised in the literature and provide surety in the findings of the review. From the research identified, none had performed a systematic review of critical factors in the reconstruction process; this research is the first to have done so.

METHODOLOGY

The systematic search of the literature was conducted in accordance with the PRISMA guidelines [8]. The procedure of undertaking a systematic review follows the following PRISMA protocol as shown in Figure 1.

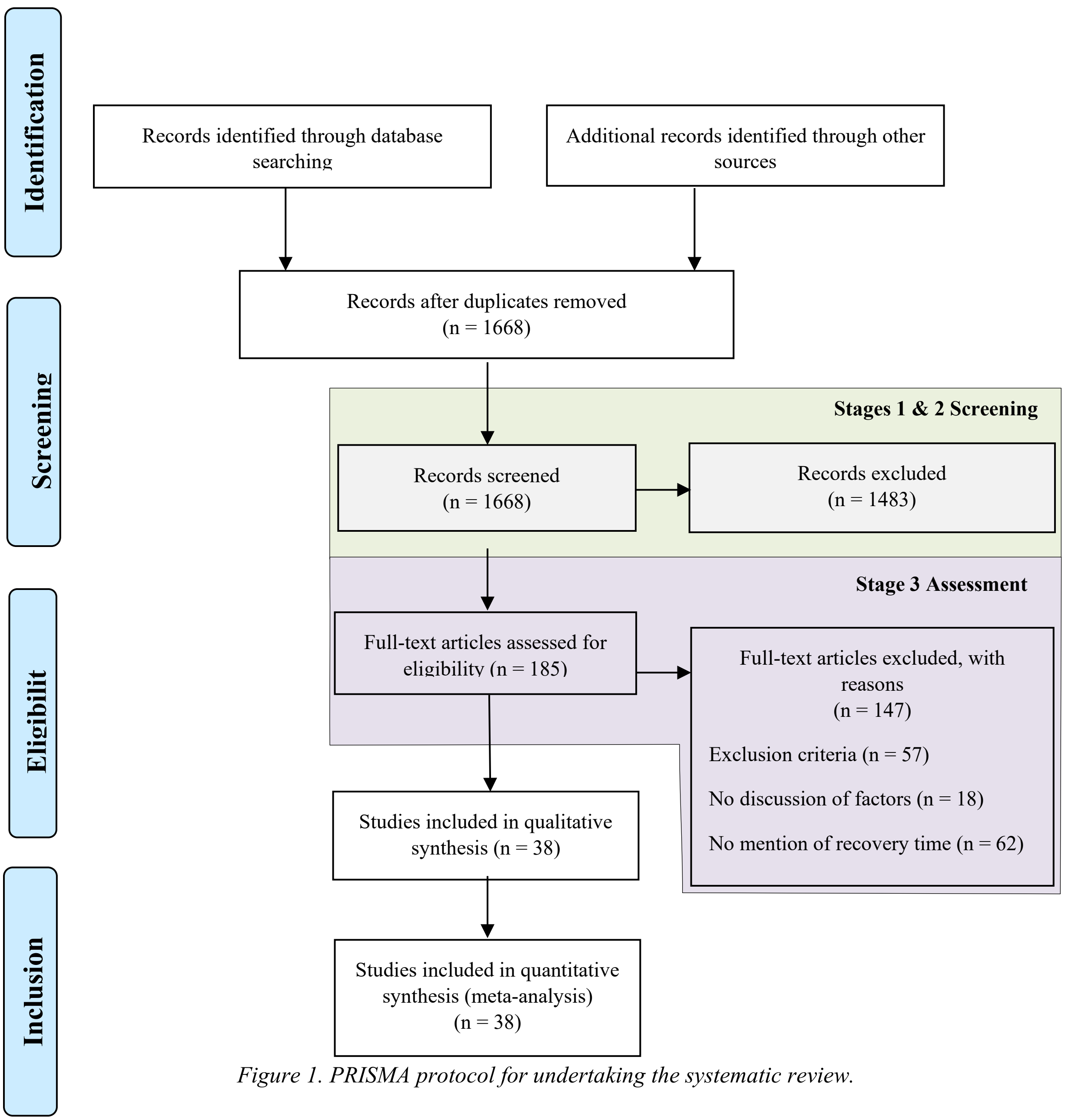

Figure 1. PRISMA protocol for undertaking the systematic review.

Search strategy

A systematic search of the databases Scopus, Google Scholar, Web of Science and the University of Auckland Library. The identification of key search keywords was crucial to ensuring for a suitable response from the search. Database output varied by size and by content relevance, due to the size of the database. The keywords “factors AND disaster AND recovery” were utilised. The database search produced 1927 records. A further 18 were identified through citation and informal searching of references.

Literature Screening

Studies that were included in the review reported on challenges, factors and key incidents that positively or negatively influenced the recovery period of infrastructure within or across the phases of infrastructure reconstruction following the impact of a sudden natural disaster. Studies underwent a three-stage screening process to establish applicability within the study. Table 2 summarises the screening that was undertaken. After screening duplicates, 1668 studies were included in the two-stage screening. In the end, a total of 38 articles were selected in this review.

Table 1. Literature screening process.

Stage 1 screening	
Inclusion criteria	**Exclusion criteria**
English literature	Medical subject literature
Literature post-2000	Duplicates
Journal articles	Non-peer reviewed articles
Government and NGO documents	Books
	Conference proceedings
Stage 2 screening	
Review of abstract or summary. Include if at least three inclusion criteria are met. Exclude if single exclusion criteria are met	
Inclusion criteria	**Exclusion criteria**
Only short-term natural hazards	Social media, internet or technology focussed
The built environment in an urban setting	Beyond urban recovery
Reconstruction - infrastructure ONLY	Any form of reconstruction that is not infrastructure based
Time	Environmental recovery
Recovery	War
	Droughts and famine
	Housing reconstruction
Stage 3 assessment	
Full Articles Assessed for Eligibility	
Exclusion criteria	
No discussion of factors	
No mention of recovery time	
Studies included in the qualitative review	
Data Extraction - Factors affecting the reconstruction of infrastructure - post-disaster	
Publication year	
Research aim and design	
Data source - sample size, disaster(s) type and location	
Recovery methodology	
Independent variables/exogenous factors	
Dependent variables/endogenous factors	

Quality assessment

An objective assessment of the literature was undertaken with a ranking provided against each journal. Weighting was made against the strength of relevance to some variables. A threshold weighting of 60% achievement was required to include the literature into the qualitative review. The quality assessment considered a number of variables included information with corresponding weightings; publication origin (15%), citations (10%), relevance of research focus (30%), relevance of factors (25%), and discussion of time (10%).

Data extraction and synthesis

Data were extracted on study characteristics: publication year, event type, event & location, publishing location and source, research aim, research mode, factors affecting infrastructure recovery time. Microsoft Excel was utilised for the recording and commentary of the literature through the review process. The manipulation and presentation of statistical data relating to the literature was also undertaken through excel. Endnote was used for reference management and citations. Studies were examined to identify all factors that influenced the reconstruction period of infrastructure at all stages. The synthesis involved observing trends and providing a narrative overview of the significance and associations within and between each factor.

It should be mentioned that there are initial conditions that also contribute to different levels of reconstruction delays. These include the size and frequency of the event, the demographics of the population, the political and economic conditions of the affected area, and the initial condition of the infrastructure [9]. While these variables are important and play a major role in the overall pace of recovery, the focus of this review is on the impact of the exogenous factors that arise during the infrastructure reconstruction process.

RESULTS

The most prominent source of research stemmed from the Christchurch earthquakes in New Zealand, second to this is USA with varying events, then China and Japan. Only research after the year 2000 was considered in this search, however all those included were published after 2006, with 90% published after 2010. Much of the research was conducted using surveys through interviews (13) and questionnaire surveys (8). Only one single study, [1] undertook a systematic review of the literature as part of the research. More studies were expected to undertake this form of research, which highlights a gap in research within this research topic. A majority of articles contained a literature review along with an active research component. This review aims to provide a well-balanced investigation into the topic of infrastructure reconstruction, with a systematic review as a central pillar to the research approach.

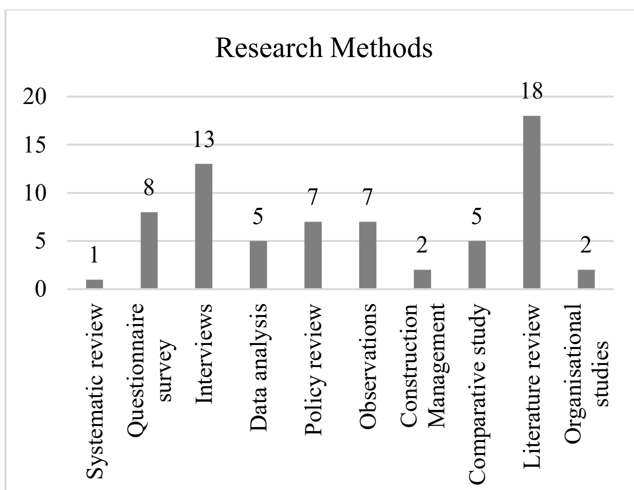

Figure 1. Methods of research within the included literature.

The infrastructure recovery process can be portioned into five discrete phases. Each phase contains a number of variables that have an impact upon the progression through the phase of recovery. These phases are roughly time progressional although there are factors within each phase that falls out of a typical construction sequence. The factors discussed in the following sections draw from literature observations and findings, which reflects the varying infrastructure recovery encounters. An initial list of critical factors was utilised from the research undertaken by [7]. This systematic review uncovered additional factors that were raised across the recovery phases that were not considered at the onset of this review. The list is considered to be a comprehensive representation of summarising factors that contribute towards delay in the infrastructure reconstruction process and is summarised in Table 3, with newly identified factors denoted in bold.

Table 2. Critical factors in infrastructure recovery.

Focus phase	Critical contributing factor	Number of journal references
Inspection and assessment time	Technical capability of engineering professionals	6
	Access to site for inspection	**3**
	Availability of engineers and speed of engineer mobilisation to undertake an assessment	6
	The existence of a robust damage inspection methodology	7
Decision making time	Changes to the building code	11
	Information management	**6**
	Land zoning decisions	10
	Preparedness and incorporation of resilience	**7**
	Consenting and permitting process	8
	Insurance claim apportionment process/process of securing finance	9
	Mechanisms of recovery governance	14
	Coordination with other sectors	13
	Community involvement in decision making	**19**
Financing time	Quantity surveying	0
	The pace of decision making of policy holder	8
	Corruption/biased allocation of resources	**6**
Adjustment time	The capacity of construction businesses	4
	Availability of construction manpower	7
	The state of the economic system	11
	Economic conditions elsewhere	6
	Availability of temporary accommodation	0
	Resource availability	**6**
	Relocation of businesses	8
	Needs perception delays - Flow of information on reconstruction work pipeline	10
Completion time	The speed of the design process	5
	Repair/rebuild procurement method	11
	Scope clarity and exposure to variations	10
	The extent of demand surge (labour wage inflation)	6
	Competency of construction labour	7
	Long lead time components and logistics	4
	The relationship between contractor and owner	**4**
	Legitimacy of stakeholders	**7**
	Power of the stakeholders	**12**
	The urgency of the stakeholders	**8**
	Resilience/Build Back Better requirement	**10**
	Cost	**6**
	Sustainability requirement	**5**
	Rework time	5

Inspection and assessment

Four studies identify the importance of having competent design professionals such as architects and engineers involved to avoid poor quality assessments and inspection delays [10-13]. Two studies noted that incorrect inspections could lead to re-evaluations, poor decision making and financial implications which all create delays [2,5]. Challenges in site access inhibit inspection and slow the initial stage of recovery [5]. Access to the site may be challenged due to the permission to be granted access onto private land [5,14]. The extent of damage to transport infrastructure can also slow access, particularly if access is required to remote areas that rely on critical road networks [15].

Four studies note a lack of availability of technical, competent staff affected the speed quality of damage assessment [2,10,12-13]. [11] identify that time pressures impact on the quality and comprehensiveness of the assessment. Quick mobilisation of engineering staff is required to rapidly understand the extent of damage across the urban setting to allow for informed decision making [2]. [16] identifies that such an inspection methodology needs to be holistic and include the ecological, social and economic parameters. [5-6,16-17] note that without a consistent methodology in place, the comprehensiveness of damage assessment is reduced. These same studies comment that time delays were incurred through the production of a methodology and the processing of non-standardised information. [2,5] discuss the need for a centralised, accessible database for documenting inspection information as crucial for effective information management.

Decision making

Nine studies note changes to building codes and guidelines during the reconstruction process [1, 6, 10-12, 20]. The term Build Back Better (BBB) was used regarding the application of updated design standards to remove failure mechanisms from infrastructure systems[19]. The incorporation of resilient materials, new technology and undertaking more resilient construction practices offer different avenues for achieving resilience, and are captured in design and construction codes [1, 6, 18-22]. [11,19] did note that the additional costs of new technology and materials can discourage adherence to the building to code, while time constraints and delays in conforming to new design codes can be prohibitive.

[6] highlight the need for a clear database management system for effective distribution of aid and building materials. [2,5,23] identify the need for a centralised, standardised and accessible database for documenting inspection information as crucial for effective information management. [5] also note that such a system enables prioritisation of efforts. Information problems can result where there are interdependencies between infrastructure systems that do not have bridging information systems [18&24].

Nine articles discuss land zoning decisions and land acquisition [e.g. 5, 11-12,14 19, 23, 25]. Government acquisition of high-risk land is cited as a cheaper way to manage recovery than to undertake reconstruction efforts, applied in Christchurch [11, 14, 19, 23]. In the Christchurch context, [2,19] discuss the resulting tension between those whose who wanted to conserve and repair existing structures and the government with the ambition of building back safer and better. [12] note that where possible, rezoning for infrastructure should be avoided due to the disruption on neighbouring businesses and community. Land zoning decisions need to consider risk exposure but also the sensitivity of those affected by the decision making - socio-economic position, land ownership and lack of economic diversification [25].

People and companies are not likely to change their living/operating patterns to reduce exposure to a natural hazard if it conflicts with more pressing and frequent considerations [25]. Experience is a major motivator to drive for incorporation of resilience into systems and processes [26-27]. This is evident with the extent of policy, design and construction practice amendments that come to effect after an event occurs. Recovery should be directed towards a new normal targeting sustainable and resilient infrastructure [28].

[10&13] identify the consenting process as a bottleneck due to a lack of qualified people and a general shortage of staff at the district level of government. [2,10,29] note the benefits of removing statutory protection measures and issue fast-track universal consents issue to speed up the consenting process. [13&19] are in favour of the simplification of the consenting procedure in Christchurch for infrastructure projects with fewer conditions with the aim of reducing the reconstruction period. [10-11, 19] identify consenting delays as a result of the incorporation of resiliency measures into the permitting process. This, however, had the beneficial outcome of an improved quality of the rebuild. [11] also notes that lengthy permitting process delays reconstruction and can discourage implementation of structural improvements to new guidelines.

[2, 5-6, 11-12, 19, 30] note the difficulties in accessing funding to undertake reconstruction. [2, 23, 31] discuss challenges with insurance claims including reaching agreement on the level of disbursement and also what constitutes as event-delivered damage in comparison to a pre-existing condition. In Christchurch, there was a feeling amongst some engineers that some decisions to demolish were unjustified and that demolition was driven by the high level of insurance penetration and by a conservative approach to safety [2]. [31] holds the presumption that in some instances, the insurer would overvalue claims which are supported by the government as they are recipients of percentage for their consulting fees. [2, 12, 19, 30] discuss the funding measures undertaken by the public sector in undertaking cost-sharing agreement between govt and council. [12] notes that government funding was staged to ensure there was sufficient money through the full recovery process. [6&11] note the need for fast action to free up funds for early recovery. [30] suggests an alternative means of recovery; using privatisation of reconstruction efforts, creating profit driven reconstruction, a process that financially benefits rather than challenges government.

[2, 13, 27, 31-32] record strong government support towards recovery in Wenchuan. [2] argues that the short-term view of government officials and legislators can lead to an avoidance of risky and disruptive decisions creating public unrest. [2, 19, 23] evaluate the effectiveness of a single agency overseeing infrastructure recovery in Christchurch. There was strong governmental support through the formation of GSDMA in Gujarat where reconstruction was a mixture of donor and owner driven approaches, requiring sustained and effective collaboration [33]. Following the Chilean 2010 Earthquake, the government did not create a recovery agency and instead relied on existing agencies to adjust and cope [30].

Issues in coordination were considered in nine journals[e.g. 2, 5-6, 16, 19, 31-32]. In the recovery setting of developed countries following a disaster, [2,5,11] identified a lack of coordination between recovery agencies in Christchurch. A similar condition was identified in the USA after major hurricane events [29]. In less developed countries, coordination challenges are discussed between the government and assisting NGOs. Large multi-level institutions including government and industry leaders struggle to suitably coordinate in a top-down, rather than a more balanced bottom-up recovery delivery model [5]. Where there are overlapping jurisdictions and responsibilities over critical infrastructure; additional challenges arise[31&35]. With a bottom-up recovery model, NGOs are focused on community engagement and involvement; they can respond quickly reducing decision making time [5]. Ensuring there is prearranged network governance and established roles of responsibility between government and other stakeholders eases coordination challenges and mitigates delays in decision making [16, 32, 35-36].

Eighteen journal articles highlight the importance of community involvement in the decision making process [e.g. 2, 5, 11, 19, 21, 25, 30, 37-38]. Community involvement is relevant for governmental and non-governmental agencies where community interaction takes place [2, 6, 32,39]. Where the community voice is not given a platform to not just voice their views but also be involved in decision making, the feelings of marginalisation and dissent can result [5, 11, 21, 25].

Financing and claim settlement

Much like engineers and project managers, sourcing quantity surveyors is a challenge due to a shortage of supply in disaster recovery settings. Quantity surveyors may face additional challenges of identifying suitable sources of material and could be forced to draw from less favourable alternative material and labour sources [1, 24&31]. However, the quality of assessment remains critical for decision makers to make decisions and allocate necessary funds for reconstruction [32&40]. [2, 12 &16]) note rapid decision making is needed in governance to ensure recovery can proceed quickly. [2, 12&16]) also note that a balance is needed between pace and effective planning. A lack of clear goals [6], poor understanding of the interdependencies in reconstruction [16&18] and short term thinking are some of the issues that arise with remissful decision making [18].

Disasters tend to weaken anti-corruption procedures and opens the opportunity for bribery in multiple forms as noted in four journal articles [9, 21, 31&36]. Corruption is a can occur in disaster recovery settings where there are conflicting agenda and no legitimate avenues to address diverging agendas [21]. The provision of labour or material resources in material and workforce resources can be directed unequally [11&19]. Inequities can be created in decision making that cause inequity between areas requiring assistance [9&31]. The outcome of the recovery can be most clearly recognised where considering areas that receive sufficient assistance and those other areas that do not.

Adjustment time (Reconstruction capacity and capability)

Construction businesses, by nature are averse to turning down projects for upcoming works. However, the financial burdens of disaster recovery can be hard to withstand [18&30]. The contractor needs to be financially resilient, whereby financial problems lead to contractual disputes and delays in construction [5&18]. Business continuity plans offer a vital safeguard to helping prepare a business for financial instability[41]. The importation of construction workers is required in severe post-disaster recovery situations [6, 13, 24&31]. The event location plays a significant factor in the availability of construction manpower [6&11]. Peak load problems create an inability to allocate labour resources to all projects [6&24]. Quick mobilisation is needed to ensure construction schedules are adhered to [23]. A shortage of labour leads to an increase in the employment costs which is transferred onto the asset owners to pay for [24].

The state of the economic system can dictate the recovery model applied to reconstruction [2, 12-13, 15-16, 24, 32]. More economically developed nations will adopt a government managed model with financial support delivered from national financial reserves, having more money available to direct towards recovery[2&9]. A less developed nation will be required to rely on foreign donations, humanitarian aid and organisational support in addition to adopting any implicit or explicit implications attached to this support [16, 18, 25&33].

Economic conditions have a direct effect on recovery performance [15, 26&32]. As an example, recovery of the Wenchuan earthquake took place during the Global Financial Crisis where the resulting recovery was slowed due to limitations in the supply of materials and labour from international markets [32]. This foreign economic influence extends to labour and material resource availability as noted by [5], competition between contractors [24&32], and even demands for recovery if there is a significant migration of people, business and money from the affected area [2&26].

This factor was expected to be a source of delay and challenge from the literature sample. This factor received government and media attention following the Kaikōura and Canterbury earthquakes due to the influx of construction practitioners [42-44]. However, the literature captured within this systematic review did not discuss the availability of temporary accommodation in any capacity. Resource availability is driven by demand-supply models. During post-disaster reconstruction, the demand for material resource increases sharply, creating an increase in competition and price [6, 24, 13&32]. Government intervention by introducing artificial pricing controls and subsidies can prevent excessive pricing [5&12]. A lack of resources; people, equipment and materials can affect the performance of the rebuild. Quick mobilisation and effective disbursement of resources is necessary for meeting time requirements [6&24].

Large firms recover more easily than small firms, and new firms tend to fail more regularly than established firms during a disaster event. Financially well-performing firms recover better by spreading risk to other locations and can afford to allocate more resources towards recovery [26, 32&41]. Property owners are more likely to stay than those who rent who favour relocation. Additionally, firms serving a non-local market more likely to relocate than those who have local market consumers [26, 41&45]. Experience in disaster continuity helps prepare a business for future risk, a sign of resiliency within the business [26&46]. Temporarily closing a business is dependent upon governmental decision making, infrastructure condition, building damage, post-disaster resource use and the ability of staff to reach the workplace [17, 45-46].

In disaster reconstruction scenarios that are not directed by a single agency, contractors are not well informed about what level of upcoming projects are going to be available. Construction businesses are forced to use a lagging metric such as completed works or visible works in construction. They will not have visibility of future projects to be released for construction [13&39]. Businesses are forced to make a judgement over the forward demand and timing of projects in the construction pipeline. Simplification of the building procedures provides more clarity to construction businesses[13]. More transparency of projects in the construction timeline gives construction businesses visibility in upcoming work as mentioned by [21], which requires a positive and collaborative transparent relationship between the contractor and the asset owner [1, 9&15].

In an alliance structure between public agencies and contractors forward workload is visible to all stakeholders. In the SCIRT alliance developed in Christchurch, contractors had oversight of upcoming work and could make informed decisions about future investments of labour, equipment and administrative costs [2, 10, 19&29].

Completion time

The speed of the design process is identified as affecting the quality and suitability of the Issue-For-Construction design and documentation package delivered for construction [11, 16&19]. Incorporating resilience, conforming to updated design codes and implementing new technologies slows the design processes [11, 19-20]. A balance is important, as a hasty design effort due to time pressures can lead to rework with changes in code and changes in decision making or a sub-optimal solution [16].

Literature suggests a wide variety of rebuild methodologies utilised in different disaster recovery settings. There needs to be a simplistic and quick reconstruction approach [5, 10, 12, 15&39]. Relying on normal contractual terminology and practice for reconstruction can create delays and frustrations as it is not suitable for application at a large-scale recovery level [10]. Adopting Agile project delivery philosophies was recommended by [12, 15&39]. Utilising an alliance delivery structure was applied in Christchurch operating under flexible contracting agreements to cater for uncertainties [5&39] In China, 93% of public works were delivered through open tender; it has been a requirement since the year 2000 that state-owned projects must follow an open tender approach [13]. Government-driven recovery was also undertaken in Nepal through a conventional contractor procurement process [37]. With whatever method undertaken, financial motivation must be maintained to ensure completion times are adhered to [24&35].

Five Journal articles recognise the importance of clear and concise documentation [5-6, 10, 15, 30]. Issues arise where there is an open or ambiguous scope; it allows for contractor interpretation and a profit-driven solution which may not align with the repair vision [10, 28&30]. Consideration of the interdependencies is crucial between the multiple forms of infrastructure requiring reconstruction [5, 15&18]. Scope change variations expose the client to cost and time implications that can harm the success of the project [11&28]. Auditing of recovery efforts should be undertaken to ensure work is progressing as per the contractual documentation, at the agreed time, cost and quality [28]. Some variations are non-avoidable such as changes to building code requirements post-project award, and these should be absorbed by a suitable contingency [11].

[5-6, 12-13, 32] all note a rise in the demand of labour in recovery. A rise in wages can result, undermining the functionality of the local construction markets. [6, 24&32] discuss the mass import of labour from abroad to offset the scarcity in labour, resulting in an increase in foreign labour. A lack of competency, experience and awareness of the core duties in the reconstruction role were the key areas noted in four journals, impacting upon the quality and speed of the project [6, 11 32&35]. Training of staff ensures that there are the necessary competencies to effectively undertake the project [6&11]. A database of skilled contractors with disaster reconstruction experience to mobilise for future events is discussed as being very valuable [11, 47-48]. Typically, the productivity of labour in disaster reconstruction is 20-30% faster than during a typical construction project [13].

The supply of materials and equipment is often affected after a significantly disruptive event. Local resources can be damaged or unavailable during the event, requiring the importation from outside sources [5-6, 24]. Importation can be slowed due to damaged infrastructure such as roads and ports [24&32]. With fewer materials available, the demand-supply balance is affected and pricing changes. Employing smart technologies such as GIS and remote sensing can enhance capacity and coordination for more effective supply chain efforts [6&11].

Infrastructure construction programming, funding and delivery characteristically require government coordination, as the asset owner. A positive, transparent relationship between the contractor and the asset owner is vital whereby differences in the agenda of stakeholders can create tension and disagreement [1, 9&15]. A strong relationship between policymakers and contractors aids in the delivery of infrastructure projects to time and budget requirements [9]. A strong relationship between stakeholders encourages public office representatives to be more inclined to draw upon social and political forces to benefit the disaster recovery project [9&15]. A poor relationship undermines trust between stakeholders and can reduce the support of values [28].

Seven journal articles consider the legitimacy of stakeholders as a core factor affecting disaster recovery [e.g. 1, 16, 18, 28, 30&39]. Legitimacy allows stakeholders to undertake their role in a social system defined by regulation, procedures and expectation [15-16]. Legitimacy improves the quality and pace of disaster recovery. Limited legitimacy reduces credibility and trust while amplifying financing and resourcing challenges [28&39].

The power of stakeholders can dictate how much support the project will receive; the size of scope, amount of funding, size of labour force assignment and quality of the engineered solution all stem from the power of the stakeholders [15-16, 18, 28&39]. This range of influence has a significant impact on the speed and quality of the project. Also requiring consideration is stakeholders external to the project delivery group, such as the wider community, which can have an impact if there is sufficient power [5, 11, 19, 32&38].

A degree of urgency is required during early recovery, in decision making and also construction. It accelerates the mobilisation of contractors and drives faster construction rates [2, 15&35]. It is important to consider interdependencies between forms of infrastructure and assets where some areas do not receive timely attention. Balancing progress with the quality of decision making and construction is noted as difficulty in many journals [6, 18&30]. Rushing the decision making and construction process can affect the applicability and the quality of the engineered solution [12, 18, 24&30]. A stage by stage assessment of the recovery process by the recovery leaders is important to evaluate the reconstruction efforts and reassign resources to areas in need [4].

Ten journal articles discuss the merits of considering future resilience in infrastructure reconstruction [e.g. 1, 6, 11, 19, 28, 31, 37]. The incorporation of resiliency into infrastructure rebuild takes additional time but provides greater protection and performance against future events [11&19]. Driving for the use of better materials, incorporation of new technology and removing failure mechanisms from the system, such as weaknesses in building codes and construction practices are some avenues for improving structural resilience [11, 19-20, 28, 31&36]. Building anthropogenic resiliency at a community level is argued as being equally important as infrastructure resiliency [1, 20&37].

Cost provides the best indicator for the duration of a construction project. It is a reflection of the scope and complexity works and also of project quality [13&18]. Due to the scale of reconstruction, the demand for materials and labour resource increases sharply, creating an increase in competition and price [4-6, 12-13, 32]. However, other factors beyond cost typically have a larger effect on the reconstruction time. Cost is a dependent factor to the increase in reconstruction time [13]. Auditing of recovery efforts is important to ensure the funding is appropriate and the construction activities are providing value and quality [28].

Sustainability is important in decision making and the design and selection of materials for construction [6, 16&28]. It is a consideration that does influence short-term timeframes but has a strong long-term benefit that outweighs the immediate inconvenience. It is a long-term strategy that must be included by all stakeholders. Sustainability needs to be considered under different but interrelated criteria across the physical, environmental, social and financial sectors as they are all related [16&38].

Rework time most often stems from poor quality construction; either in the finish, non-conforming details or deviation to initial design [11-12, 28&30]. Inspections during construction are crucial to avoid rework [11-12, 30]. Minimum standards of construction should be communicated between stakeholders to avoid the need for rework [18]. Rework time is also evident in the amendment of policy due to rushed decision making [30].

CONCLUSIONS

This review has highlighted that challenges in infrastructure recovery are synonymous regardless of recovery setting, process and type of infrastructure affected. One can appreciate that there are many factors that can create delay and disaster recovery scenarios are expected to encounter a number of these factors. With this in mind, it is hard to estimate the impact these factors will influence the recovery time, and the interaction between recovery phases was not particularly well covered in the literature. As an example, there was a lack of discussion about how a slow inspection and assessment phase create additional pressures in decision making where the quality of decision making is affected. Challenges in one recovery phase are expected to have influential effects upon the succeeding phases. There needs to be a further investigation into the relationship between factors and how these factors influence one another.

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