Build Back Better principles for post-disaster structural improvements

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Abstract

Purpose – The purpose of the paper is to inform stakeholders involved in post-disaster reconstruction how to incorporate Build Back Better (BBB) principles when implementing structural design improvements to achieve efficiency and effectiveness in the rebuilding process.

Design/methodology/approach – Literature review was used to establish BBB principles required for post-disaster structural changes. The application of these principles was then tested in the Indian Ocean Tsunami reconstruction in Sri Lanka, and the Victorian Bushfires in Australia. Qualitative data were collected in each country by conducting interviews with stakeholders from governmental authorities, and non-governmental and community-level organisations who were directly involved in recovery activities along with other documentation. Results were compared to understand how/to what extent BBB principles were applied and their implications, to finally determine the applicability of these principles in different environments.

Findings – Proposed BBB principles for post-disaster structural changes from literature were grouped under: building codes and regulations, cost and time, and quality. Principles such as multi-hazard-based building codes, education and support for communities, long-term funding and quality assurance through inspections were applicable in both case studies. Experiences in Australia and Sri Lanka also presented a few extra principles to add practicality based on local contextualisation. These included avoiding high-risk lands using buy-back/land-swap schemes, incentives to attract skilled builders, and the use of comfortable temporary accommodation to relieve time pressures.

Research limitations/implications – The study does not look into detail at the administrative, regulative and social systems which contributed towards the inability of the built environment to withstand the respective hazards. A general understanding of these systems was gained and taken into consideration when analysing the results. The findings show that despite the differences found between Australia and Sri Lanka the relevance of the principles for structural improvements remained intact.

Practical implications – The government, engineers and building practitioners involved in reconstruction will benefit from learning from the experiences of others, and understanding how implementing structural changes can be done more successfully by applying BBB principles.

Originality/value – This research takes a unique look at how BBB principles drawn from international experiences can be incorporated when implementing structural changes in post-disaster rebuilding to further improve the outcome.

Keywords Build Back Better, Reconstruction, Indian ocean tsunami, Victorian bushfires, Natural disasters, Hazards

Paper type Research paper

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Introduction

The increasing frequency and magnitude of disaster events in recent times are a result of climate change, urbanisation, increased exposure to natural hazards (an extreme natural event/process) and variations in coping capacity of people (Red Cross, 2010; Sugiyama, 2011; Wisner *et al.*, 2005). The devastation caused by disasters to vulnerable communities have led to greater focus on finding ways to improve the efficiency and effectiveness of post-disaster recovery activities (Lloyd-Jones, 2006). Researchers such as Boano (2009), Khasalamwa (2009) and Ozcevik *et al.* (2009) proposed that the reconstruction phase should be used to not only restore communities to their pre-disaster states, but to take the opportunity to create safer, more sustainable and resilient communities, underpinned by the theory of "Build Back Better" (BBB) (Clinton, 2006; James Lee Witt Associates, 2005), where resilience is defined as the capacity to absorb stress or destructive forces through resistance or adaptation (Twigg, 2007). Creating disaster resilience in vulnerable communities is important for the future to cope with the adverse effects of climate change.

"BBB" first emerged during the multi-national recovery effort following the Indian Ocean Tsunami (Clinton, 2006; Lyons, 2009) with the intention of using a holistic approach towards reconstruction and recovery where the physical, social and economic conditions of a community are collectively addressed to create overall improved resilience (FEMA, 2000; James Lee Witt Associates, 2005; Khasalamwa, 2009; Roberts, 2000). The report "Key Propositions for Building Back Better" produced by the former US President Bill Clinton presents ten propositions to achieve BBB (Clinton, 2006). Other frameworks and guidelines published presenting BBB concepts include: "Holistic Recovery Framework" (Monday, 2002); "Building Back Better: way forward" (Disaster Relief Monitoring Unit of the Human Rights Commission of Sri Lanka, 2006); "*Lessons from Aceh: Key Considerations in Post-Disaster Reconstruction*" (Da Silva, 2010); and "Rebuilding for a more sustainable future: an operational framework" (FEMA, 2000).

Analysis and grouping of recurring themes emerged from the above guidelines and recommendations from international research showed three key concepts which represent BBB: first, risk reduction, second, community recovery, and third, implementation. Risk reduction focuses on structural and non-structural measures such as hazard-based land-use planning to reduce the vulnerability of the built environment. Risk (R) is defined as a product of the hazard (H), vulnerability (V) and capacity to cope (C), ($R = (H \times V/C)$ (DN and PA, 2008); and vulnerability is defined as characteristics that influence the capacity to anticipate, cope with, resist and recover from the impact of a hazard (Wisner *et al.*, 2005). Risk Reduction is represented by two BBB principles: Principle 1 – Improvement of Structural Designs, and Principle 2 – Land-use Planning. Community recovery entails supporting psycho-social and economic recovery through two principles: Principle 3 – Social Recovery and Principle 4 – Economic Recovery. Implementation addresses the means by which risk reduction and community recovery initiatives can be executed efficiently through Principle 5 – Stakeholder Management, Principle 6 – Legislation and Regulation, Principle 7 – Community Consultation and Principle 8 – Monitoring and Evaluation. These eight BBB principles when implemented simultaneously would lead to building back better during reconstruction and recovery. The BBB principles also work in combination with other strategies such as emergency preparedness strategies and natural environment-related strategies.

Whilst all the BBB principles are being studied in-depth individually and with relation to each other this paper addresses only the first BBB principle: Improvement of

Structural Design. The data collected focuses exclusively on the use of structural measures for risk reduction in order to develop a set of BBB principles to aid in implementing post-disaster structural design changes to improve infrastructure resilience. A comparative case study approach is used with the 2004 Indian Ocean Tsunami in Sri Lanka and the 2009 Victorian Bushfires in Australia selected as case studies. BBB principles for post-disaster structural improvements are identified from the literature review. The principles are then used to analyse the reconstruction effort in the two countries. The results enables the determination of what impacts adoption/non-adoption of the principles have had on the successfulness of the reconstruction process, and discloses the applicability of the principles in different environments. Modifications to the original BBB principles for post-disaster structural changes will be proposed based on the findings. These principles will assist stakeholders involved in post-disaster reconstruction to improve the efficiency and effectiveness of implementing structural design changes.

Improving structural designs using BBB principles

A primary reason for extensive damage from natural disasters is the inadequate structural capacity of the built environment. The damage from the 2004 Indian Ocean Tsunami (DN and PA, 2008) and the 2009 Samoan Tsunami (Bird *et al.*, 2011) was partly due to insufficient consideration of coastal risks in the design of structures. The destruction from the Kashmir Earthquake in Pakistan was again traced to non-earthquake resistant building design and construction in earthquake-prone areas (Halvorson and Hamilton, 2010). Similar cases were apparent in the 2010 Haiti Earthquake and the 1995 Kobe Earthquake disasters (Ellsworth, 1995). Dias *et al.* (2006), Halvorson and Hamilton (2010) and Mora and Keipi (2006), amongst others, attribute destruction to the built environment from disasters to factors forming vulnerabilities such as: incomplete/inaccurate assessments of hazards; lack of consideration of climate change effects; incompatibilities between structural designs and hazard levels; lack of consideration of risks in town planning; inexistent or neglected building codes and regulations; rapid population growth which results in illegal occupancy on high-risk lands; and the lack of disaster awareness in the community. These factors result in various types of vulnerabilities such as physical, social, political and environmental vulnerabilities.

Clinton (2006) said “a key test of a successful recovery effort is whether it leaves survivors less vulnerable to natural hazards”. BBB advocates that reconstruction provides an opportunity to incorporate risk reduction measures while damaged structures are being rebuilt to eliminate pre-existing vulnerabilities and increase resilience to future hazards and the effects of climate change (Mercer, 2010; Palliyaguru and Amaratunga, 2008).

The importance of reviewing and changing building designs and codes to improve the structural integrity of buildings and infrastructure following a disaster is widely understood (Halvorson and Hamilton, 2010; McCurry, 2011; Meigh, 2009), but is, however, less frequently attained successfully in practice due to a range of common issues. Poor regulative powers and the lack of strict enforcement can lead to building code changes being disregarded resulting in sub-standard structures in the rebuild (Asian Development Bank, Japan Bank for International Cooporation and World Bank, 2005; DN and PA, 2008; Nathan, 2010). When the Indian Ocean Tsunami struck, enforcement of building codes was mainly restricted to urban and suburban areas in Sri Lanka. The rural and coastal areas were the main victims of the disaster, where the lack of strict structural standards resulted in magnified damage (Palliyaguru *et al.*, 2010;

Pathiraja and Tombesi, 2009). Extra costs incurred by adopting new technologies and materials to improve structural resilience also discourage compliance of new building codes (Batteate, 2005; Kijewski-Correa and Taflanidis, 2012). The findings of Egbelakin *et al.* (2011) indicate that confusion created by contradicting information and the perception of building owners about the risks of another disaster event in the near future contribute towards the scepticism about building strengthening in New Zealand. As soon as a disaster strikes it is common to see recovery efforts addressing only the just-experienced hazard, which can exacerbate vulnerabilities to other hazards (Kennedy, 2009). Time pressures in the recovery process with expectations for fast results also largely contribute to hasty design and construction in the absence of well thought out building codes and hazard assessments (Kennedy *et al.*, 2008). The last factor that contributes to poor structural integrity is the quality of workmanship during construction. It is common practice for non-governmental organisations (NGOs), imported trades work force and home-owners to assist with reconstruction projects leading to inconsistent quality in the rebuild (Boano, 2009; Khasalamwa, 2009; Pathiraja and Tombesi, 2009).

The experiences of post-disaster reconstruction efforts worldwide have provided lessons which can be adopted as principles when implementing structural changes to avoid the above mentioned issues and BBB. The principles naturally group under: building codes and regulations, cost and time, and quality.

Building codes and regulations

- hazard-based building regulations should be created using multi-hazard assessments in areas chosen for redevelopment and reconstruction (Batteate, 2005; FEMA, 2000; Haigh *et al.*, 2009; United Nations, 2005);
- consistent regulations and a strong legal framework will assist the adoption of building codes and regulations and ensure that structural changes improve the built environment (Clinton, 2006; Iglesias *et al.*, 2009; Mora and Keipi, 2006); and
- the community and stakeholders must be educated about adopting community-inclusive risk reduction/building practices and changed regulations (Ikeda *et al.*, 2007; Reddy, 2000).

Cost and time

- long-term funding needs to be made available to cover extra costs for structural improvements (DN and PA, 2008; James Lee Witt Associates, 2005);
- adoption of new building regulations should be promoted using appropriate incentives such as tax reductions (Bakir, 2004; Edwards, 2010); and
- pre-planned strategies for structural changes to deal with post-disaster environments will reduce planning/preparation times and make the recovery process more efficient (Disaster Relief Monitoring Unit of the Human Rights Commission of Sri Lanka, 2006; Olshansky, 2005).

Quality

- inspections during construction by local governmental authorities should include a focus on quality (Lewis, 2003);
- training to stakeholders involved in design and construction on new design and construction information required for the rebuild is needed (James Lee Witt Associates, 2005; Lloyd-Jones, 2006);

- quality should not be compromised for speed (Clinton, 2006; Grewal, 2006); and
- owner-built reconstructed houses will require high tolerance for human errors and require professional supervision (Pathiraja and Tombesi, 2009).

This research uses these post-disaster structural changes principles as a guide to understand the case studies undertaken and further develop these principles.

Research method

A comparative case study approach was adopted using two case studies to establish findings. The Indian Ocean Tsunami disaster was chosen as this event initiated the concept of BBB and provides a valuable resource for the early understanding and application of BBB principles and their long-term impacts. The Victorian Bushfires was chosen to investigate how much the concept of BBB has been integrated in post-disaster recovery operations in a more recent event. The case studies had many differences between them in aspects such as economic situation, population density, type of hazard, governmental and administrative structure, culture and ethnicity. These differences present the opportunity to understand whether the applicability of BBB principles vary or display universality in different reconstruction environments.

Qualitative data were collected for the two case studies by visiting the impacted areas in Sri Lanka and Australia and conducting semi-structured interviews with a range of stakeholders. Interviewee details are presented in Tables I and II. Participants from both countries were asked to comment on the implementation; implications; challenge; and recommendations for risk reduction using structural changes in the post-disaster practices of each country; and their awareness of BBB. Evidence from post-disaster documents including progress reports, commission reports and government reports were used to validate the findings where possible.

The stakeholders interviewed in Sri Lanka (Table I) were from national-level governmental regulatory authorities (CCD, UDA) who were responsible for development plans and land-use regulations; local governmental authorities (Galle Municipal Council, Galle Divisional Secretariat) who implemented recovery activities at the local level, NGOs

Interviewee code	Number of interviewees	Organization
P1-P5	5	Disaster Management Centre (DMC)
P6	1	Asian Disaster Preparedness Centre (ADPC)
P7	1	United Nations Development Programme (UNDP)
P8	1	Practical Action (PA)
P9	1	Coastal Conservation Department (CCD)
P10	1	National Building Research Organisation (NBRO)
P11	1	Care International
P12	1	Urban Development Authority (UDA)
P13	1	Galle Municipal Council
P14	1	Galle Divisional Secretariat
P15	1	Peraliya School

Source: Author

Table I.
Profiles of the interviewees in Sri Lanka

Research trip	Interviewee code	Number of interviewees	Description
Research Trip 1	P16-P24	9	Victorian Bushfire Reconstruction and Recovery Authority (VBRRA)
July 2010	P25 and P26	2	Building Commission
	P27	1	Temporary Village
	P28	1	Local Council
	P29 and P30	2	Volume Builders
	P31 and P32	2	Department of Human Services (DHS)
Research	P33	1	Fire Recovery Unit (FRU)
Trip 2	P34	1	Building Commission
July 2011	P35	1	Office of Housing, DHS
	P36	1	Department of Planning and Community Development (DPCD)
	P37	1	Economic Recovery, FRU
	P38	1	FRU
	P39	1	Marysville Community Recovery Committee
	P40	1	Marysville Chamber of Commerce

Source: Author

Table II.
Profiles of the interviewees in Australia

(UNDP, ADPC, Practical Action and Care International) who were involved in rebuilding work and dealt closely with affected communities, a local affected school (Peraliya school) to provide a community perspective, and the DMC which is the national-level organisation established under the Sri Lanka Disaster Management Act No. 13 of 2005 after the tsunami to coordinate disaster management activities in the country.

The Victorian Bushfires affected sites were visited on consecutive years in 2010 and 2011 where stakeholders interviewed (Table II) included officials from the recovery authority established to oversee the recovery and reconstruction activities (VBRRA and FRU), government officials in charge of community recovery (DHS), officials involved with structural regulation changes (Building Commission), rebuilding advisors who helped the community with rebuilding (VBRRA and FRU), builders, local council for the local council perspective, town planners who were developing the new urban plans (VBRRA), and representatives from local community organisations who were involved in grass-roots level activities such as community consultations (Marysville CRC, Marysville Chamber of Commerce).

A combination of deductive and inductive approaches using Grounded Theory and the Constant Comparative Method were used to analyse the data (Maykut and Morehouse, 1994; Yin, 2009). Key recurring themes were identified from the literature review, which were used to code the transcribed interview data using the computer programme NVivo 9. The data were in turn used to refine the identified themes and develop the categories and principles presented in this paper.

Case study backgrounds

The tsunami waves resulting from the 9.0 magnitude earthquake which occurred off the coast of Sumatra, Indonesia on 26 December 2004 impacted 14 countries including Sri Lanka, which suffered substantial damage (Cosgrave, 2007). In total, 13 out of 25 coastal districts in the East and South of the country were affected with 35,322 lives lost, 516,150 people displaced and approximate direct losses of $1 billion (Asian Development Bank, Japan Bank for International Cooperation and World Bank, 2005; Frerks and Klem, 2005). At the time of the tsunami Sri Lanka did not have strictly enforced building codes for residential developments (Society of Structural Engineers, 2005) and had complicated and time-consuming permit procedures which were largely ignored (DMC, CCD and ADPC, 2011) leading to vulnerable settlements in high-risk areas such as the coastal belt. Following the tsunami all the rebuilding work and livelihood support were handed over to the NGO sector, and the Task Force to Rebuild the Nation (TAFREN) and the subsequent body the Reconstruction and Development Agency (RADA) were established to coordinate and assist stakeholders in the rebuilding phase (GoSL, 2005).

The second case study, the Victorian bushfires took place on the 7 February 2009, where fires swept through 78 communities in the state of Victoria. 173 lives were lost, and more than 430,000 hectares of land, 2,000 properties, 55 businesses, 3,550 agricultural facilities, 70 national parks, 950 local parks and 467 cultural sites were destroyed (VBBRA, 2009). Some of the areas affected by the Victorian bushfires were not declared as bushfire-prone before the event. The Australian building code for bushfire-prone areas, AS 3959 was also still in the process of being updated with the findings from the 2003 Canberra bushfires when the 2009 fires occurred. The absence of accurate up-to-date mapping and planning and construction regulations contributed towards worsening the impact of the fires. Both the case studies demonstrated pre-disaster vulnerability to hazards.

Results and discussion

Information about the structural measures taken to improve post-disaster resilience in the two countries is presented below under the three categories that emerged from analysis of literature: building codes and regulations; cost and time; and quality.

Building codes and regulations

It is usual practice to see building codes and regulations changed following a disaster, but reconstruction in Sri Lanka was primarily based on relocating communities away from high tsunami risk areas, with less focus on improving structural designs (Pathiraja and Tombesi, 2009). P2, P10 and P13 stated that this led to the construction of sub-standard vulnerable structures after the tsunami. Although the "Guidelines for building at risk from natural disasters" was published in October 2005 to aid the Sri Lankan tsunami rebuild (Society of Structural Engineers, 2005), P13 said that "construction did not happen according to the guidelines because of the rush". The NBRO interviewee explained that the structural building code system was not practiced widely in Sri Lanka especially for housing construction, which remained the case during reconstruction. P5, P7 and P11 commented that the tsunami-rebuild was not successful and highlighted the need for regulatory authorities to assert control over the structural integrity of buildings through the use of building codes and regulations. Building guidelines and codes are now being prepared to address different hazards.

In Australia several days after the bushfires a revised edition of the Australian Standard for construction of homes in bushfire-prone areas (AS:3959) was released (VBBRA, Building Commission and CFA, 2010). P25 from the Building Commission confirmed that AS 3959-2009 "contained more stringent design and construction specifications for better bushfire protection" which was concurred by P16, P17 and P30. P34 explained that compliance was enforced through the use of permit procedures.

A common problem encountered in Sri Lanka was people being relocated into areas prone to different types of hazards without adequate counter-measures in building designs which increased vulnerability. Sole focus on bushfire risk alone was also seen in the Australian rebuild, although consequent impacts have not been observed as yet.

Australia provided a good example of how structural changes can be implemented for risk reduction through revising building codes and enforcing permit procedures to BBB, reflecting the first two BBB principles for structural changes stated in the literature review. Since Australia already had a background of conforming to building regulations during construction, the same process was applied successfully in post-bushfire construction. Sri Lanka on the other hand displayed an unsuccessful outcome due to the lack of practice in conforming with structural regulations. However, the shortcomings in Sri Lanka were recognised in the long-term by observing the resulting vulnerable building stock and have led to re-examining building codes and regulations for future construction similar to Australia.

A key theme that emerged from the interviewee data were that in order to BBB, consideration of all potential hazards concurrently is more effective when choosing building sites and determining necessary structural requirements. Hazard assessments must realistically include climate change impacts which can intensify the magnitude of disasters (He and Qiu, 2011) in order to provide appropriate structural solutions. The principle from literature stating that regulations should be created based on multi-hazard assessments reflects this finding. The adverse effects of disregarding this principle were observed in Sri Lanka. Education and training of stakeholders as recommended by in literature were not explicitly implemented in either of the case studies. The success rate of adopting structural changes may have been higher if the community and stakeholders had been educated about the implications and trained on how to adopt them.

Cost and time

The most common cause for the reluctance in adopting structural improvements in both countries was the resulting increased cost: "Incorporating disaster risk reduction into improving the resistance of sea-side houses (to withstand the impact of coastal hazards) will result in large cost increases which are not feasible", said P9 and was reiterated by P33, P36 and P38. P18 provided an example in Victoria where "a house in BAL FZ zone (the highest risk zone) would now cost $70,000-90,000 over and above what it would cost to build a normal house" which is a substantial cost increase that is unaffordable for many people. P22, P23, P28, P29 and P33 stated that the rebuild in Australia was driven by the availability of insurance, which meant that people who did not have sufficient insurance were unable to afford the changes required for their homes. Although the Victorian Bushfire Appeal Fund (VBAF) provided grants for construction, P33, P38 and P39 pointed out that the lack of regulation around how the money was to be utilised resulted in people spending the money without saving enough for construction. In Sri Lanka the main source of funding was from donations, which were plentiful, but donation-use was constrained due to donor agendas, political influence and corruption (GoSL and UN, 2005; Khasalamwa, 2009). P6 and P11 added that the funding was short-term and was not able to sustain construction projects over time, whereas long-term funding was needed for full reconstruction.

Despite the source of funds being different in the two countries, both cases exhibited a common issue regarding the lack of funds to implement structural changes in high-risk areas. Principles from literature advocate that long-term funding should be provided along with monetary incentives to promote adoption of risk reduction strategies. The lessons from the case studies demonstrate a few suggestions that can overcome commonly encountered issues. The proposed improvements for structural designs must be within manageable and realistic cost and time limitations to ensure compliance. The government could take responsibility for funding the extra cost required for improvements not covered by insurance, or restrict construction on high-risk lands requiring improvements which are too costly and time-consuming. A suitable option for lands on which construction costs cannot be covered by insurance or government funding is the introduction of "Buy-back" or "Land-swap" schemes, where high-risk lands are either bought by the government, or exchanged, allowing occupants to settle into lower risk lands.

The implementation of improved structural regulations was also hampered by the extra time required, which P18, P19 and P25 in Australia declared was inconvenient in an environment where speed was crucial. P18 commented that "when the special materials specified in the regulations were not available delaying construction, some people started building without waiting for these materials". Lengthy and time-consuming permit procedures discouraged the implementation of structural improvements in Sri Lanka: "The problem is in Sri Lanka most of our procedures are very long, so NGOs weren't willing to spend time on these things", said P14. P8, P11, P13 and P14, as well as Khasalamwa (2009) and Boano (2009) stated that NGOs had to work under pressure to meet deadlines to satisfy beneficiary expectations which drove them to focus on speed. The provision of comfortable temporary accommodation in Australia allowed most affected people to remain patient and move into well designed, safe homes, stated P27, P31, P32 and P40. Temporary accommodation was provided in Sri Lanka, but was uncomfortable and unsuitable for local conditions which intensified the need for people to move into proper homes, said P11 and P14.

It is evident that fast progress in reconstruction is anticipated by the community and donors, but ignoring procedures for speed resulted in a poor result as evidenced in Sri Lanka. Not choosing quality over time led to unfavourable outcomes in both countries. The Australian experience shows that providing comfortable transitional homes that can house affected people for a considerable period of time can reduce time pressures allowing structural changes to be made properly. The focus, however, should remain on permanent construction and long-term reliance on temporary accommodation must be avoided. A pre-planned strategy as recommended in literature would have made the recovery efforts of both countries more efficient.

Quality

The quality of the designs and construction influence safety, which is determined by the skill level of the builders used for the rebuild. P34 explained that "because of the remoteness of these areas, and because the building industry was very strong in Victoria, it was difficult to get builders and tradesmen to the bushfire areas". P1, P22, P23, P28 and P29 commended the rebuilding advisory service set up by VBRRA which was valuable for people to ensure their rebuilding work was being done correctly. In Sri Lanka the reconstruction was either donor-driven or owner-driven and although some NGOs maintained high-quality standards, P6, P9 and P12 pointed out that the lack of awareness of some international NGOs about local guidelines and regulations contributed to the construction of inappropriately built structures. The findings from GoSL and UN (2005) also showed a lack of skill and experience of NGOs who were involved in post-tsunami reconstruction. P11, on the quality of homes stated that in owner-driven homes "people often started doing extensions, adding more stories on houses designed for 1-storey loads etc which compromised their structural integrity". P10 and P11 both stressed the importance of regulative authorities taking charge of conducting inspections to ensure that construction is being done according to the specified guidelines. P15 agreed that supervision and support from trained personnel would give more confidence to locals when building.

Issues with quality were common to both countries which were addressed in literature such as by providing training to building practitioners; conducting inspections; and not compromising quality for speed. Further to this, incentives can be provided to attract skilled builders to become involved in reconstruction operations, such as provision of financial aid, subsidised resources and accommodation options at the rebuilding sites. Having a database of skilled builders who are willing to participate in post-disaster reconstruction during the pre-disaster phase would also assist in guaranteeing construction quality. Problems with owner-driven construction were observed in Sri Lanka. Although owner-participation should be promoted, providing close professional supervision and using designs with high tolerance for human errors as suggested in literature is required.

Conclusions

The implementation of structural changes during post-disaster reconstruction to improve structural resilience can be achieved more successfully by adopting BBB principles related to structural improvements. The BBB principles for structural changes were categorised under Building Codes and Regulations; Cost and Time; and Quality based on analysis of existing literature.

Having analysed the Australian and Sri Lankan case studies, results show that the principles for structural changes were universally applicable in both cases despite the legal, political, social, cultural and administrative differences. Hazard-based building regulations using multi-hazard assessments which take disaster risk reduction and climate change into account are required for rebuilding. The adoption of building codes must be supported by having a strong legal framework in place. The community and building practitioners must be educated about the importance of improved building regulations. Long-term funding must be provided to cover extra costs incurred by structural improvements, along with incentives provided to promote adoption of building codes. Quality assurance must be strictly monitored through regular inspections. Training must be provided to update building practitioners on new regulations.

The experiences in Sri Lanka and Australia have also provided a few more modifications to make the BBB principles more practical. The first recommendation is to restrict costly and timely construction on high-risk lands. Buy-back/land-swap schemes can be put in place to assist with this. Time pressures on reconstruction should also be relieved by using comfortable transitional accommodation. Some extra time can then be spent on performing thorough hazard assessments, conducting stakeholder training programmes, revising building codes, consulting the community and other necessary activities to provide the best possible solutions. The quality of the rebuild will be enhanced by using skilled builders. Incentives such as accommodation options and subsidised resources can be provided to attract skilled builders to take part in the rebuild. Establishing a database of potential builders in the pre-disaster period who would be interested in taking part in reconstruction activities would also make the process more efficient. Having a pre-planned strategy is key to a successful reconstruction process.

The current study and its findings are limited to knowledge from literature and the experiences in Sri Lanka and Australia. Testing of these principles on further case studies with different country settings is required to test the true universality of the principles for structural changes and to prove whether they are able to overcome local contextualisation.

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