Proceedings

Disasters and the Built Environment

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CIB Task Group
TG63 - Disasters and the Built Environment

Papers from the Designated Session Disasters and the Built Environment that took place
as part of the CIB World Building Congress, Brisbane, Australia, May 2013, under
the responsibility of Task Group TG63 - Disasters and the Built Environment

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Under the 2010-2013 mandate, the aim of the Task Group is:
• to bring together international perspectives and activities related to disaster risk reduction in the built environment from socio-technical and socio-economic perspectives.
• to develop context sensitive ways of incorporating disaster risk reduction principles, and measuring the impacts of such principles, in building, construction and reconstruction activities at community/local, regional and national levels and across a range of low-, middle- and high-income nations.
To accomplish this, the Task Group will:
• encourage new international, collaborative and multi-disciplinary research activities that will interact with the private and public sectors and governmental and non-governmental agencies.
• develop, share and disseminate appropriate research methodologies and disaster risk reduction initiatives that are appropriate to building, construction and reconstruction activities at local, regional and national levels.
In this context the specific research objectives are:
• to define how disaster risk reduction can be implemented in building, construction and reconstruction activities in various contexts and for various stakeholders
• to develop context sensitive disaster risk reduction principles and clear methods for implementation of these principles for building, construction and reconstruction activities
• to validate and refine the disaster risk reduction principles for building, construction and reconstruction activities based on previous and emergent research findings.
Papers from the Designated Sessions that took place as part of the CIB World Building Congress, Brisbane, Australia, May 2013, under the responsibility of Task Group TG63 – ‘Disasters and the Built Environment’.

The context
It has been argued that the broad range of people responsible for the delivery, operation and maintenance of the built environment need to become more proactively involved in making cities resilient to a wide range of known and unforeseen hazards and threats. Accordingly, the United Nations International Strategy for Disaster Reduction (UNISDR) with the support of CIB has been campaigning to help cities and local governments to get ready, reduce the risks and become more resilient to disasters. By drawing upon the UNISDR’s campaign, and other global and local initiatives, these conference sessions examined the multi-disciplinary perspectives of how cities can be made more resilient, incorporating associated physical, social, economic and institutional issues.

The papers
The sixteen papers presented in the TG63 sessions have gathered research results and studies related to ‘Making cities more resilient’ from across the world. The amount of papers submitted for the TG63 sessions also highlights that proactively dealing with disaster risks in the built environment is becoming an increasingly important part of the CIB’s activities.

Some of the overriding messages from these insightful papers highlight that despite regulatory guidance designed to increase urban resilience through the use of public and private sector stakeholders, there are a number of operational obstacles that need to be surmounted. It is suggested that there are a range of strategies required to overcome these obstacles; these strategies are likely to include revisions to regulations and building codes, the tightening of planning policy, improvements to professional training and communications, and developing good practice guidance about a broad range of structural and non-structural risk reduction measures etc. However, pragmatically it is clear that there is the need to understand how a broad range of construction stakeholders can be better informed and incentivised to take a more proactive role in building-in resilience. Therefore, while these papers indeed provide valuable suggestions and insights into how disaster risks can be reduced there is still more work to be done to better understand how the operational obstacles can be overcome across a range of contexts. The future work of CIB through TG63 (and related task groups and working commissions) will be tasked with addressing these matters over the next few years.

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<table>
<thead>
<tr>
<th>Papers</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Study of Construction Productivity after the 2011 Christchurch Earthquake in New Zealand</td>
<td>1</td>
</tr>
<tr>
<td>Kelvin Zuo, Suzanne Wilkinson and Jeff Seadon</td>
<td></td>
</tr>
<tr>
<td>April 2009 Earthquake in Central Italy: Initial Considerations About Reconstruction Costs</td>
<td>14</td>
</tr>
<tr>
<td>Antonio Mannella and Antonio Martinelli.</td>
<td></td>
</tr>
<tr>
<td>Assessing Regulatory Framework Efficacy for Seismic Retrofit</td>
<td>26</td>
</tr>
<tr>
<td>Implementation in New Zealand</td>
<td></td>
</tr>
<tr>
<td>Temitope Egbelakin</td>
<td></td>
</tr>
<tr>
<td>Capacity Building to achieve Sustainable Water Management System in Arid and Semi-Arid Lands (ASALs)</td>
<td>36</td>
</tr>
<tr>
<td>Akanksha Sinha, Saumyang Patel and Makarand Hastak</td>
<td></td>
</tr>
<tr>
<td>Cities and Flooding: Lessons in resilience from case studies of integrated urban flood risk management</td>
<td>48</td>
</tr>
<tr>
<td>Jessica Lamond, Robin Bloch, Zuzana Stanton-Geddes and David Proverbs</td>
<td></td>
</tr>
<tr>
<td>Critical Factors for Successful Housing Reconstruction Projects Following a Major Disaster</td>
<td>62</td>
</tr>
<tr>
<td>Zabihullah Sadiqi, Vaughan Coffey and Bambang Trigunarsyah</td>
<td></td>
</tr>
<tr>
<td>Determinants of Urban Resilience: an exploration of functional response diversity in a formalising settlement in the City of Tshwane, South Africa</td>
<td>73</td>
</tr>
<tr>
<td>Albert Thomas Ferreira and Chrisna Du Plessis</td>
<td></td>
</tr>
<tr>
<td>Disaster resiliency measurement frameworks state of the art</td>
<td>85</td>
</tr>
<tr>
<td>Leila Irajifar, Tooran Alizadeh and Neil SipeLeila</td>
<td></td>
</tr>
<tr>
<td>Exploring a Methodological Framework for Understanding Adaptive Change in Cities</td>
<td>99</td>
</tr>
<tr>
<td>Darren Nel, Chrisna Du Plessis and Karina Landman</td>
<td></td>
</tr>
<tr>
<td>Information Provision and Communication Strategies for Improving Earthquake Risk Mitigation</td>
<td>111</td>
</tr>
<tr>
<td>Temitope Egbelakin</td>
<td></td>
</tr>
<tr>
<td>Seismic safety of places of worship in Italy's Gran Sasso and Monti della Laga National Park</td>
<td>123</td>
</tr>
<tr>
<td>Aurelio Petracca, Carmela Morisi, Giandomenico Cifani and Giovanni Cialone</td>
<td></td>
</tr>
<tr>
<td>Should the Disaster Management Strategies in Bangladesh be just about</td>
<td>135</td>
</tr>
</tbody>
</table>
Constructing New Shelters?
Muhammad Nateque Mahmood, Subas Dhakal and Md Kamruzzaman

Social resilience in the context of South African cities: Exploring the interdependencies of urban and social resilience
Trudi Swanepoel and Chrisna Du Plessis

Temporary Housing Residents' Satisfaction Analysis: A Case Study in Southern Taiwan
George Yao, Po-Tsung Chen, Li-Fan Liu, Ju-Huey Wen and Che-Ming Chiang

The Performance of Houses in the Canterbury Earthquake Sequence
Graeme Beattie

The threat of slow changing disturbances to the resilience of African cities
Edna Peres and Chrisna Du Plessis
Higher productivity is desired in the construction market. The recent earthquakes in Christchurch have resulted in changes in the way that the construction sector works. The changes in the sector present an opportunity to study the effects on improving productivity and to apply the lessons learnt to the wider New Zealand construction environment. This paper reports on initial results of a pilot case study in Christchurch over residential buildings utilizing a composite approach. The research proposes to examine productivity of different residential buildings for each phase (e.g. deconstruction, rebuild and ongoing maintenance) and a number of buildings in each phase at different stages (e.g. floor, outside walls, roof, etc.) for case studies. Interviews in the research with different stakeholders involved in the whole life cycle of residential buildings (e.g. architects, engineers, builders, etc.) identify potential areas for productivity improvements. The study aims to answer what legislative and process changes have been made for Christchurch deconstruction, rebuild and on-going maintenance and its short-term and anticipated long-term effect on productivity.

Keywords: Construction Productivity, Christchurch, Case Study

1. Introduction

The construction industry is a significant part of the overall economy. According to Arditi and Mochtar (2000), the construction industry accounts for 6–8% of an economy’s Gross Domestic Product (GDP). An improvement in construction productivity performance not only would produce direct benefits in the sector, but could also provide substantial cost savings. An increase of 10% in the UK construction labour productivity is equivalent to a saving of £1.5 billion to the industry’s clients, sufficient to procure approximately 30 hospitals or 30,000 houses per year (Horner and Duff 2001). In New Zealand, the building and construction sector contributed around 4% of the GDP in 2010, almost the same as agriculture. This is less than in other countries, with the sector representing 7% of GDP in Australia, 8% of GDP in the UK and 9% of GDP in the USA (Building and Construction Productivity Partnership 2012). The workforce of construction industry in New Zealand represents 8% of those in employment. In the last 10 years, 14% of all new employment in New Zealand has been in the building and construction sector.
Productivity Partnership 2012). A Government Productivity Taskforce recently found that construction sector productivity in New Zealand is declining and is low compared with other industries and other countries (Department of Building and Housing 2009).

The Building and Construction Productivity Partnership has developed a set of indicators believed to affect construction productivity improvement in New Zealand at firm, sector and national level (Building and Construction Productivity Partnership 2012). Factors believed to affect productivity such as increased investment in education and training, more innovation and better integrated supply chain have the potential to lead to construction productivity improvements. Figure 1 shows the productivity indicators and the impact of these at the organisational level. The Productivity Partnership is committed to improving construction productivity by 20% by 2020, by making improvements to the ways in which the construction industry operates under different indicators. Canterbury offers a unique opportunity to study changes in productivity because the region is undergoing such rapid changes to its construction sector following the earthquakes. The region is actively seeking ways to become more productive as the rebuild intensifies.

**Figure 1: Key drivers of productivity improvement in New Zealand (Building and Construction Productivity Partnership 2012)**

The 2010 and 2011 earthquakes in Canterbury have resulted in changes in the way that the construction sector operates, in particular in some of the processes being used. The rebuild programme may offer opportunities for improvements in some of the factors, such as more standardisation, more innovation and better waste management. This paper presents findings from a research project which examined changes to the construction sector in
Canterbury and the effect of these changes on construction productivity. The paper highlights positive and negative changes and recommends the positive lessons are applied beyond Canterbury, so that the whole of the New Zealand construction sector can benefit from potential productivity improvements. The research reported here focuses on the productivity changes in construction components and processes as experienced through construction residential projects in Canterbury after the series of earthquakes.

2. Research Design

The paper covers the following areas: 1) The impact of recent legislative/regulatory changes on construction productivity in Canterbury; 2) Whether construction process changes have been made in Canterbury, and the effects of any changes on construction productivity; 3) The construction productivity factors considered to be most important by interviewees. Case studies of different residential buildings at different life cycle phases were carried out to get a whole of life perspective as shown in Figure 2. Interviews were carried out with construction stakeholders involved in the full life cycle of residential buildings.

Figure 2: The Whole Life Cycle of a Building (Seadon 2012)

The principle for the selection of construction projects for case studies in this research was to cover the Canterbury residential building sector in deconstruction, rebuild, and maintenance phases. The interviews were conducted with key stakeholders involved in the projects. Interviewees include representatives from the contractor, the consultant/designer, and the government authority. Each interviewee provided the following information: 1) Interviewee and project information; 2) Legislative/regulatory changes – the top five legislative changes which have the most impact on construction productivity were identified (the impact could be either positive or negative); 3) Process changes – Information on the process changes during the Christchurch deconstruction, rebuild and on-going maintenance were provided. The top five process changes in terms of their impact on construction productivity were identified; 4) Productivity factors – The top three factors under each productivity category: external, internal (labour), and internal (management) were identified. The top five productivity factors from all categories irrespective of which group they belonged to were listed; and 5) Long-term effects – Information on the long-term effects of the top changes in legislation and processes on construction productivity were identified by interviewees based on their experience as were the practices that have the potential to improve construction productivity.
The interviewees were asked to describe a typical deconstruction, rebuild, or maintenance project they are currently operating in Christchurch. The locations of surveyed projects covered the whole of Christchurch area, with the majority of them in more severely damaged eastern and southern suburbs. Most of the reconstruction projects were under the Design and Build (D+B) arrangement for residential buildings, with minority were adopting the prefabrication method (factory built then transported and assembled on site). The typical duration of the project ran from 3 to 5 months, with around 10 people required for the building process. The exceptions were projects managed by the larger contractors, with scopes ranging from 3 to 5 years and investment in hundreds of millions of dollars. The contract price of a residential rebuild project varied with an average of NZD $353,000. A total of 14 interviews were conducted in the first two weeks of July 2012. Interview profiles can be found in Appendix 1.

Specific reference to a known project is intentionally avoided to ensure the anonymity of the interviewees. The information/data is collected in a consistent way across different types of projects and is presented in the same unit/format for comparison. The selection of interviewees is one per project. The selection of interviewees in this research was based primarily on their specific role/function and experience in the construction industry. It covers almost every industry functions as demonstrated in Figure 2, the whole life cycle of a building, with the majority of them on design, construction, and maintenance. Besides the government official, the interviewees have an average of more than 16 years’ experience in the construction industry, with the longest one reaching 35 years. Less than 30% of them were assigned to their current position after the first Christchurch earthquake on Sep 2010, more than 70% of the interviewees were already in a senior management role before the earthquake happened.

3. Research results

3.1 Legislative and regulatory changes

The legislative and/or regulatory changes that have been made as results of the 2010 to 2011 Christchurch Earthquakes are summarised in the Christchurch Earthquake Recovery Authority (CERA) website (CERA 2012). They include changes to legislation that have been made in response to the earthquake, including Orders made under the Canterbury Earthquake Recovery Act 2011, and Orders and Regulations made under the Canterbury Earthquake Recovery Act 2010 and under other legislation. Among those, the ones that are directly related to the on-going Christchurch deconstruction, rebuild and maintenance are mainly addressing the following aspects to facilitate: 1) The Earthquake Commission (EQC)’s repair of residential land and property in Canterbury; 2) Reserves to be used for response and recovery efforts; 3) Councils to deal with dangerous building situations (Building Act related issues); 4) Resources Management Act related issues; and 5) Other relevant issues such as the rating valuations, balancing rebuilding and protecting historic places, or registration of imported heavy vehicles for recovery purposes, etc.

Some of the legislative/regulatory changes listed on CERA website (2012) that are not directly related to the purpose of this research (deconstruction, rebuild, and maintenance process) are not considered. However, they might indirectly influence the recovery of the
Canterbury built environment, such as those in relating to social security, education provision, energy, transportation, local government, and tax administration.

From the research for this project, the top five legislative changes which have the most impact over construction productivity (the impact could be either positive or negative) were categorised as follows: 1) Canterbury Earthquakes Recovery Act 2011 (CERA Act) related issues, such land zoning, geotechnical report requirements, etc.; 2) The Earthquake Commission’s (EQC) regulations around release of the funding for reconstruction projects and engineering assessment; 3) Building code changes; 4) Health and safety regulations; and 5) Orders in council/regulations facilitating the deconstruction process, such as allowing temporary accommodations on site, logistics allowing shifting wide loads, and fast-track demolition.

The most mentioned legislative change was the CERA Act 2011 relating to land zoning issues, different foundations and geotechnical reporting requirements. The impacts felt from the CERA Act 2011 were: slowing down reconstruction; bureaucratic red tape around zoning and the slow process of obtaining geotechnical and engineering evaluations. The positive potential long term effects of CERA Act 2011 were thought to be seen in improvements made to the land through taking time to be thorough with evaluations. The second most mentioned change was EQC’s policies in relating to the release of funding for reconstruction. Most of the interviewees regarded the EQC related regulation changes as negative on construction productivity. The significant volume of the work contributed to the slow process. The comments received were: work not being able to start until EQC have released payouts; tightening of EQC sign-off which were slowing processes; lack of communication from insurance and EQC. However, it was also felt that realistic expectations were needed of EQC and the insurance process because of the number of people available to undertake the work compared with the volume of work required. The relationship between EQC and insurance companies and its impact on homeowners needed to be further improved.

Building code changes were identified in the interviews as key changes affecting productivity. However, unlike CERA Act 2011 and EQC, most of the interviewees (75%) who mentioned the building code changes regarded them as necessary, more practical (such as allowing more space for slab deflection parameter), and improving the industry, and were positive about their impact on construction productivity long-term, if not immediately. Code changes create a more resilient building system against future events. However, there was concern expressed at the different building requirements for foundations which would slow the rebuilding process and required different equipment to undertake the work. Building code changes created different relationships with different subcontractors, and required new understanding of the legislative requirements for different types of work.

Health and safety regulations were affecting productivity reported by the interviewees, including scaffolding requirements and personal protection policies increasing thus slowing the work. Comments were received that health and safety regulations were making the reconstruction process take longer and costing more, but were necessary. Deconstruction and recycling related regulations reported by the interviewees were facilitating the re-build process. Deconstruction and recycling related regulations such as relocating houses,
transportation, and fast-track demolition, moving loads day and night, were beneficial according to responses. Ratings of overall impression of legislative and regulatory changes experienced so far on Christchurch construction productivity as either positive (increase productivity), neutral (do not affect productivity, or decrease initially but will benefit productivity in the long term), or negative (decrease productivity) is shown below.

![Figure 3: overall impression of legislative and regulatory changes on Christchurch construction productivity](image)

### 3.2 Process Changes

The construction process changes experienced during the current recovery in Christchurch were identified. The top five process changes in terms of their impact on construction productivity were listed as: 1) Local councils' consenting process; 2) The availability of skilled labour; 3) EQC and insurance; 4) Unresolved land issues; and 5) Internal process changes.

More than half of the interviewees ranked local councils' consenting process as top in their impact list on construction productivity. The majority of comments received were negative about the experience, feeling the process has slowed the rebuild. The comments referred to taking a long time to obtain consents; fear of the Council being unable to cope; impractical requirements; confusion; a business as usual process being used; and the costs of consents increasing. New staff in Council positions and the lack of clarity around procedural requirements were part explanations for the delays. Adequate and advanced planning for consents and inspection were practical suggestions to contractors to avoid delays. Increased difficulty in recruiting skilled labour and qualified engineers for rebuild was seen as impacting productivity. Interviewees believed that as the Canterbury reconstruction is still at a very early stage, the shortage of skilled labour would become more significant especially if related issues, such as temporary accommodation needed for construction workers, are not managed well. Additional issues rose with skills and labour included the potentially incompatible labour skills with different build methodologies and the integration of different cultures within the construction team.

Insurance companies and EQC were generally seen to be having a negative impact on productivity. Comments such as requiring itemised quotes and reducing rates were impacting on time and cost. Homeowner exhaustion was commented on as affecting the rebuild, including having to engage with reappraisal requirements or having problems getting the insurance resolved. Homeowner expectations needed to be better managed.
Disagreements between EQC’s assessment and the insurance company’s assessment on their portions of the settlement payment were further compounding the problem, slowing the rebuild. Sorting out multi-event assessments, early assessment and later assessment differences were causing problems and slowing the rebuild process. Unresolved land issues, such as land zoning status and subsequently different building requirements for different types of foundation, are interconnected with insurance, local councils’ consenting processes, and legislative changes. Unresolved land issues are a result of the legislative changes following the Canterbury earthquakes. Without resolution the Council cannot issue consents and EQC and insurance cannot settle claims. Clearer information on the land repair expectations is required. Within the interviewees’ organisations changes have been taking place that affect productivity, these are referred to as internal process changes. Examples given were: 1) Creating own in-house design/ engineering consultant team; 2) Longer design and planning processes; 3) Changes in business operating; and 4) Changes in procurement methods.

Because of the difficulty of finding engineering consultancy firms to undertake work, one contractor reported that they formed their own in-house engineering team to support the increased amount of new work. Longer design and planning processes are being experienced due to the increased volume of work and more reporting requirements in the process. These were referred to by some interviewees from the contractors’ side as “internal bureaucracy” of additional reporting requirements in the design and planning phase to the designer and council. With workload increasing, subsequently changes have been experienced on the way a typical privately-owned construction firm, with less than 5 employees, operates its business. Changes such as: procedural changes, i.e. moving from chasing an inquiry to choosing work; dealing with different stakeholders, such as the insurers; more up-front costs; more time and more communication; better budgeting and more networking. The procurement methods used in the Canterbury recovery, especially on large scale projects, are changing from the traditional design-bid-build model to more collaborative and integrated arrangements, such as the Alliance model. This might not be observed in the relatively smaller size projects in residential market yet, but the overall desire for more efficient procurement methods is reported. As work progresses there are expectations for more efficient processes through the Project Management Offices (PMOs) making procurement faster. Overall impression from the interviewees of the impact of the process changes experienced on construction productivity as either positive (increase productivity), neutral (do not affect productivity, or decrease initially but will benefit productivity in the long term), or negative (decrease productivity) are presented in Figure 4.

![Figure 4: Overall impression of process changes on Christchurch construction productivity](image-url)
3.3 Productivity factors

Productivity factors were categorised into 3 major groups: 1. External – factors affecting productivity which were beyond the control of management; 2. Internal – Technological (Labour) factors affecting productivity – factors within control of management, focusing more on the technology and labour; and 3. Internal – Administrative (Management) factors affecting productivity – factors within control of management, focusing more on administration.

3.3.1 External factors

The top 3 factors identified in External Category - factors affecting productivity which are beyond the control of management, were: 1\textsuperscript{st}: Possible aftershocks; 2\textsuperscript{nd}: Availability of skilled labour; 3\textsuperscript{rd}: Size and complexity of the project. The most common external factor affecting productivity was the influence of continuous aftershocks on reconstruction progress. 93\% of the interviewees chose “possible aftershocks” as an influencing factor, and 43\% ranked it top of their list. The uncertainty associated with these aftershocks brings slow progress on land zoning, damage assessment, and insurance settlements. The availability of skilled labour was ranked as the second most important external factor influencing construction productivity in Christchurch. The third issue ranked was the size and complexity of the projects, 86\% of the interviewees chose size and complexity of the projects and 43\% ranked it within the top 2 in the external category.

3.3.2 Internal - Technological (Labour) Factors

The top 3 Internal – Technological (Labour) factors affecting productivity – which are factors within control of management, focusing more on the technology and labour were: 1\textsuperscript{st}: Quality of craftsmanship; 2\textsuperscript{nd}: Quality control and quality assurance practices & Wages and benefits; 4\textsuperscript{th}: Worker attitude and morale. Quality is critical for project success. Decreasing quality decreases productivity as rework and waste become problems. Proper processes are required to make sure quality is to the required standard but training to meet the standard was required, especially as the rebuild increases pace. Standardization of building methods, materials used, quality assessment methods, model houses, etc. or generally, standardisation of the construction industry, was thought to offer a way to control and improve quality. Worker attitude and morale was believed to be an important factor influencing construction productivity. When asked about the current situation, interviewees gave more negative comments than positive ones on worker’s attitude and morale based on their direct experience. There is a mix of factors that are driving this, such as the anticipation from the workers (of better wages and on-going contracts) and the lack of actual reconstruction jobs. Frustration has arisen from perceived low pay rates and the feeling of the repair and rebuild work not being well organised. Poaching between companies and constant changes in companies can affected company morale. It is happening and is feared that the situation will get worse.
3.3.3 Internal – Administrative (Management) factors

The top 3 factors identified in the internal – administrative category are: 1\textsuperscript{st}: Changes in drawings and specifications; 2\textsuperscript{nd}: Lack of cooperation and communication between crafts; 3\textsuperscript{rd}: Lack of detailed planning. 64\% of the interviewees selected “changes in drawings and specifications” and 36\% ranked it as the top productivity influencing factor under the internal-administrative category. The lack of cooperation and communication between crafts leads to difficulties in coordinating subcontractors and ranked as second most internal productivity influencing factor. Lack of detailed planning ranked as third most influencing administrative factor affecting construction productivity.

3.3.4 Overall ranking of productivity factors

The most important issues influencing construction productivity in the recovery were ranked in the following order: 1\textsuperscript{st}: size and complexity of the project; 2\textsuperscript{nd}: possible aftershocks & availability of skilled labour; 4\textsuperscript{th}: wages and benefits; 5\textsuperscript{th}: quality of craftsmanship. The focus should now be on those issues most likely to bring productivity improvements, such as improving the availability of labour, improving wages and benefits, focussing on quality and worker morale during the rebuild.

3.4 Applicability of lessons learnt in Canterbury to other parts of New Zealand

From the research, some of the lessons of the Canterbury rebuild could transfer to other parts of New Zealand. The New Zealand industry could collectively benefit from Canterbury recovery experience in terms of increased construction productivity in the long term. For instance, the alliance model could encourage more collaboration and partnership arrangements. Relationships between regulators, the construction industry and the insurance industry have built up quickly in Canterbury, and any positive experience, such as better understanding and collaboration among these parties could be transferred to other parts of the country. Lessons in speeding up processes and accelerating projects could be transferred to other parts of the country. Training of a workforce could be a benefit to the future New Zealand construction industry. Bringing in overseas employees with different skills, cultures and education will affect the construction industry and could lead to potential long-term productivity improvements.

3.5 Reaching a 20\% increase in productivity by 2020

43\% of the interviewees were unsure about the goal of reaching 20\% increase in productivity by 2020, with positive and negative answers equal. No obvious common themes or patterns were observed, but most of the negative comments were concentrating on issues such as the lack of resources, and the lack of willingness to change from New Zealand’s ‘fragmented’ construction industry. In order to reach the goal of 20\% increase in productivity by 2020 the research found that there needed to be fundamental changes to the way the industry operates, such as new ways of thinking, constructing, educating and new processes. Suggestions were made by the interviewees on the practices believed to have the potential to improve construction productivity in Canterbury and New Zealand. The following six areas...
were offered: 1) Prefabrication; 2) Management training for the construction sector – e.g. lean project management principles; 3) Chance for collaboration and new ideas to be accepted; 4) Training of more skilled labour; 5) Standardization; and 6) Innovation and technology- education and trialling.

Prefabrication for reconstruction is well supported by the interviewees to increase construction productivity because it generally makes rebuild cheaper and quicker. But the difficulties in achieving a greater market share of prefabrication in New Zealand were acknowledged. Shifting the view and perception of people of a prefabricated building from ones of a 1980’s classroom to a new modern sustainable residential building is one of the challenges for prefabrication. Proven quality record about the prefabrication houses and the availability of commercially available materials (in large quantity, competitive price, etc.) for building/assembling prefabrication houses are needed. However, the market for prefabrication still appears small so the rebuild offers a chance to use prefabrication on a wider scale bringing productivity improvements to the construction industry. The prefabrication is not being called for because of a lack of understanding and acceptance of the idea among the potential homeowners. Canterbury rebuild provides a chance to trial new ideas such as prefabrication. Demo houses and villages were built up in Christchurch (organised by Prefab NZ) to showcase new building ideas hoping the demand will increase.

The Canterbury reconstruction offers a chance to grow and expand management training for the construction industry. Adopting new management techniques such as lean project management to deliver better value with less waste was mentioned as a potential positive impact. In addition, the recovery provides the opportunity to try new ideas and more collaborative contractual arrangements into the construction industry, such as the alliance model for project delivery. Typically the alliance model is used on larger and more complex projects where there is a large amount of uncertainty as the size and duration of the project has to justify the investment in setting it up both commercially and culturally, and the participating organisations need to develop and nurture a culture of collaboration throughout the system beforehand in order to manage such projects. These criteria fit in well with the Christchurch reconstruction situation and are reflected in the interviews. Companies reported the rebuild had provided the environment for sharing building ideas, sharing and solving problems and improved networking. The trust experienced and more collaborative relationship established during the rebuild process will benefit normal time construction in the future.

The more significant skilled labour shortage is a concern for the reconstruction, so smarter ways of training and educating are required to produce more skilled labour. This necessitates better wages and benefits to attract and retain labour. There will be productivity gains felt across New Zealand in terms of better skilled and qualified labour. Standardization to speed up the construction process could bring productivity improvements. Standardization in design, quality control, building methods and procedures were all possibilities for productivity improvements. A greater level of research and development into more innovative, fast build processes would increase productivity. The general impression from the answers to the last part of the interview was that the recovery provides a chance for trialling more innovative technologies.
4. Conclusion

The Canterbury earthquakes have presented an opportunity to change the construction industry and improve construction productivity. This paper highlights the main areas of the negative impact on construction productivity caused by some of the legislative and process changes for the industry in Canterbury. Legislative changes have forced consideration of different ways of operating. The majority of the criticism was seen around land zoning issues, councils’ consenting process, and EQC and insurance related issues which had the effect of slowing down the reconstruction process. The long term effects of those legislative and process changes on construction productivity in Christchurch will bring opportunities for innovation, more collaboration, and better value for money. Capturing changes to processes and improvements in construction productivity during the rebuild will have significant positive impact on productivity in New Zealand.

Lessons learnt from Canterbury experience in terms of disaster preparedness will no doubt be applicable to other parts of the New Zealand. The majority of interviewees believed that the construction industry will benefit from Canterbury recovery experience. Possible productivity improvements could be made from improving the availability of skilled labour, improving quality, focussing on worker morale and encouraging innovative procurement practices and these improvements will also benefit New Zealand. Gain in productivity will come from industry standardization in design, better building methods, such as prefabrication and better management training. Fundamental changes to businesses that transfer the knowledge gained from legislative and process changes to ensure integration and consistency of interpretation across the whole supply chain will be required.

References


## Appendix 1

The information of interviewees and associated construction projects are summarised below:

<table>
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<tr>
<th>Interview #</th>
<th>1</th>
<th>2</th>
<th>3</th>
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**Interviewees and project information**
April 2009 Earthquake in Central Italy: initial considerations about reconstruction costs e procedure

Antonio Mannella¹, Antonio Martinelli²

Legislation regulating earthquake reconstruction work in Italy

Italy is a country frequently struck by earthquakes of medium intensity. In April 2009, an earthquake swarm that had been carrying on for several months reached its climax with an earthquake measuring 5.9 on the Richter scale. A heavily built-up area of Central Italy was hit with damage to a large number of buildings and very many people affected. In particular, the city of L'Aquila, situated close to the epicentre, is the regional capital with an important old town centre and plenty of industry. The earthquake caused 308 deaths, 1600 injured and damage to more than 40,000 buildings. In May 2012, a new seismic event, comprising 3 tremors of magnitude greater than 5, struck the Emilia-Romagna Region in the north of Italy, causing 17 deaths, hundreds of injured and more than 17,000 homeless. Reconstruction following the 2009 earthquake and regulated by Act No. 77/2009 was handled in a much different way to previous earthquakes. Actions to reconstruct business premises, residential housing, public and monumental buildings were soon implemented with around 22,000 damage repair projects financed in the three years since the earthquake, of which 10,000 have already been completed and 12,000 are in progress. The paper provides some figures regarding the amounts actually spent, with particular reference to the grants received to repair ordinary buildings. A critical analysis has also been made of the statutory solutions adopted in order to finance damage repair operations, highlighting their strengths and weaknesses and the possible scope for improvement.

Keywords: earthquake, seismic vulnerability, buildings, damage, reconstruction costs

1. Introduction

Following a seismic event with very serious consequences, such as that which occurred in Central Italy on 6th April 2009, in a scenario where only a very small number of properties are insured, the starting point for handling the reconstruction is the drafting of specific legislation regulating the damage repair work. The seismic event in question, culminating with an earthquake of magnitude Mw 6.3, struck a heavily built-up area, causing 308 deaths and more than 1600 injured, whilst making more than 35,000 buildings uninhabitable (data from survey using AeDES forms last updated February 2011). In addition to housing, the
categories of buildings damaged include business premises, public and monumental buildings. Act 77-2009 specifies the manner in which compensation is paid for earthquake damage, this being based on financing the detail drawings for the repair work. The procedure is completely different to those adopted following previous earthquakes in Italy where funding would be granted according to certain parameters such as the building’s surface area, degree of damage and vulnerability; such legislation may be considered prescriptive and called for several steps: 1) determination of the extent of damage to each property and consequent allocation of a specific class; 2) calculation of the maximum permitted grant according to the building’s allocated damage class, certain seismic vulnerability parameters and a few other characteristics such as the presence of primary residences or businesses, etc.; 3) preparation of the detail drawings for the repair work and execution. On the other hand, the legislation implemented following the 2009 earthquake may be considered performance-based since it does not allocate the building a preassigned classification based on the maximum permissible grant and does not require the execution of specific types of work, but simply specifies the level of seismic safety to be achieved, this being decided by the result of the building safety assessment following a brief survey immediately after the earthquake. Act 77/2009 also calls for immediate preparation of detail drawings for the repair work that will be used to check that the estimate is fair and the work proposed is necessary. The implementation of this legislation has allowed repairs to properties with light damage (safety rating "B" or "C") to begin very quickly, but various shortcomings have been noted when dealing with more seriously damaged buildings (safety rating "E"). For the reasons just explained, in order to deal with the reconstruction of the buildings damaged by the earthquake that struck Northern Italy in May 2012 (Mw 6.0, 17 deaths, around 17,000 homeless), the legislator has introduced some notable changes to the regulatory framework specified by Act 77/2009, preferring an approach in many respects similar to that of previous legislation.

2. The reconstruction costs of the 2009 earthquake

For the first time in Italy, government grants to repair damage were awarded on the basis of the results of the safety assessment carried out straight after the earthquake and the detail drawings for the repair work. On the contrary, after previous earthquakes, grants were calculated according to parameter-based costs and preliminary damage and vulnerability assessments carried out by designers following safety assessments. Details follow of the various steps specified by the above-mentioned Act 77/2009 in order to qualify for a grant to repair damaged property.

2.1 Surveying damage and safety in the post-earthquake emergency

Surveying damage and assessing safety are priority tasks in the post-earthquake emergency. Such activities allow identification of the structures and areas that could represent a risk to the population and those that may continue to be used, thus reducing inconvenience to citizens and possible further damage. In 1997, a joint working group of the National Earthquake Protection Group and National Earthquake Service comprising distinguished members of the Italian civil service and scientific community designed a form for surveying the damage, authorising emergency repairs and assessing the safety of
ordinary buildings after the earthquake. This form had already been tested in areas of the Marche Region struck by an earthquake on 26th September 1997. Known as the "AeDES form", it was subsequently included in the Joint Operations Centre (COM) Technical Management Manual approved in November 1998 by the National Commission for the Forecast and Prevention of Major Risks and following improvements it was also used after later earthquakes in various parts of Italy. The form is split into 9 sections; the first 3 provide unambiguous identification of the building in question and include a description and details of construction type, the others contain a description of the damage and any emergency work already carried out or needed to prevent further damage and in conclusion allocate a safety rating. The form enables completion of a quick survey and initial cataloguing of building stock since it contains details of building type and dimensions. The manual in question defines the concept of safety (and therefore usability) as follows: "The safety assessment in a post-earthquake emergency is an expeditious, provisional assessment - meaning that it is based on an expert opinion and completed quickly by means of visual inspection and collection of readily-accessible information - that aims to establish whether, in the presence of a seismic event, the buildings that have previously been struck by the earthquake can continue to be used, providing a reasonable level of protection of human life."

There are 6 usability ratings, of which the most important, also used for allocating grants, are safety rating "A" (building usable, no significant damage, low risk, the entire building may be used without putting the life of its occupants at risk), classes "B" (building temporarily uninhabitable, localised damage, medium risk, simply requires certain emergency repairs in order to enable use of the entire building without risk for its occupants) and "C" (building partly uninhabitable, localised damage, medium risk, the condition of certain areas of the building is such as to place the occupants at very high risk) and class "E" (building uninhabitable, serious damage, high risk, no part of the building may be used even after completion of emergency repairs).

<table>
<thead>
<tr>
<th>CATEGORIES ACCORDING TO USABILITY FORM (AEDES FORM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Usable building</td>
</tr>
<tr>
<td>B Usable building following emergency work</td>
</tr>
<tr>
<td>C Partially usable building</td>
</tr>
<tr>
<td>D Building to be reassessed</td>
</tr>
<tr>
<td>E Unusable building</td>
</tr>
<tr>
<td>F Building unusable due only to external risk</td>
</tr>
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Figure 1: No. of AeDES forms completed per municipality and brief description of usability ratings
2.2 Allocation of repair grants

As happened following previous earthquakes in Italy, Act 77/2009 provides for grants to cover the cost of repairs and seismic retrofitting of buildings damaged by the 2009 earthquake. Unlike previous earthquakes, the Act in question does not set limits to the amount of the grant, there being a specific reference to the possibility of "covering the entire cost of repairs, reconstruction or purchasing of similar accommodation"; furthermore, with prevention in mind, the Act also provides for the allocation of additional funds for damaged buildings for the “maximum reduction of seismic risk”.

Act 77/2009 also calls for the appointment of a Government Commissioner and the enactment of Prime Ministerial Ordinances in order to implement its provisions. Following the Prime Ministerial Ordinances, various decrees and circulars were enacted by the above-mentioned Government Commissioner. The use of a further two levels of legislation in addition to the original Act (Prime Ministerial Ordinances and Government Commissioner Decrees) has led to delays and created a great deal of confusion, thus creating an unnecessarily complicated and chaotic regulatory framework. Act 74/2012 regulating post-earthquake reconstruction in Emilia Romagna does away with the intermediate step of the Prime Ministerial Ordinances, thus restoring the regulatory approach adopted prior to the 2009 earthquake.

Taking their lead from the provisions of said Act, the subsequent implementing measures have split the grant into two categories: one for damage repairs, covering as much as the full cost, and the other for seismic risk reduction with a maximum lump-sum payment calculated according to the outcome of the building’s safety assessment.

Another important difference compared to the legislation adopted following previous seismic events concerns the necessity to prepare detail drawings for the repair work as a first step, including a written estimate from the building contractor, before the grant application can be considered.
The grant application, complete with detail drawings for the repair work and bill of quantities, is approved by the local council (Commune) assisted by a support unit that carries out checks according to preset criteria. After the preliminary checks are complete, the Commune approves the grant for repair work. Payment is made from funds previously allocated in accordance with progress reports. While the work is in progress or following completion, the Commune performs random checks in order to verify the correct execution of the work.

In the case of previous earthquakes, the safety assessment was followed by an intermediate stage that allowed the building to be classified in a certain grant category according to the amount of damage suffered and verification of a number of preset vulnerability parameters. The grant was therefore first calculated according to certain parameters on the basis of the category allocated to the property and then paid off gradually as the work progressed. So in the past, there was no need for approval of the entire set of detail drawings for the repair work, its compliance with certain parameters specified by the emergency legislation was deemed sufficient. In most cases, a minimal amount of seismic retrofitting of the property was requested, but the overall project was subject to less specific checks.

Unlike in the case of previous earthquakes, the legislator’s choices with regard to the post-earthquake reconstruction of 2009 have allowed immediate financing and execution of the work, eliminating the intermediate step of building classification that had been necessary in the past. It has also allowed more careful control to be exercised over projects and the grants given, since checks are carried out, in particular on the detail drawings, in order to confirm the fairness of the proposed costs and scope of work. Other than in an initial settling-in period lasting just a few weeks, the mechanism has worked rather well as regards the funding of repair work for lightly-damaged buildings (with usability rating B or C). The table below shows the number of grant applications received, the number approved and the amount allocated in million euro.

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<td>7 615</td>
<td>70.23</td>
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<tr>
<td>B</td>
<td>8451</td>
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<td>C</td>
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<td>E</td>
<td>9901</td>
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<td>1 569.88</td>
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<tr>
<td>TOTAL</td>
<td>27 073</td>
<td>21 731</td>
<td>2 188.02</td>
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</table>

The following figure illustrates the average total unit cost of repairs to buildings with a B or C usability rating as a function of gross floor area.
Figure 5: Average total unit cost of repairs to buildings with a B or C usability rating

By contrast, the complexity of repair projects and the consequent complexity of carrying out checks has caused long delays in granting funds to finance projects for more seriously damaged buildings (with "E" usability rating), thus leading to a backlog of several months in dealing with applications.

The initial absence of an upper limit to the size of a grant at first led to very overpriced estimates of the cost of repairs to buildings with the most damage. In many cases, the engineers consulted recommended elaborate, but extremely costly, solutions that were often not economically viable when considering the property’s market value. In order to guarantee more efficient management of the funds available, the legislator introduced what has been coined “feasibility limit”: the size of the grant given for repairs and seismic retrofitting of an existing building has been capped at the equivalent cost of constructing a brand new building of the same size. The actual implementation of this legislative amendment took several months, from May 2010, date of issue of Prime Ministerial Ordinance 3881 ratifying the principle of the feasibility limit, to December of the same year, date of publication of Government Commissioner’s Decree No. 27 providing the implementation criteria.

The legislation in question set a time limit for processing grant applications and releasing funds with which the Municipalities’ inspectorates rarely managed to comply. The average time needed to process applications for lightly-damaged buildings (B or C safety rating) was 140 days, instead of the 90 specified by the Act (the Act specified that a Municipality should process applications within 60 days, along with a further 30 days to allow the engineer in charge of the project to hand over additional paperwork). In the case of applications regarding more seriously damaged buildings, legislative requirements were completely ignored, since the average time necessary for the release of funding was 340 days. The figures below show the average time needed for the release of funding according to the quarter in which the application was submitted.
2.3 Delays in releasing funds for E-rated buildings

As previously stated, the checking and approval process of repair projects for buildings with an "E" rating took far longer than expected. Indeed, for seriously-damaged buildings, the Act specified that a Commune should process applications within 90 days, comprising 60 days for the Commune to examine the detail drawings and 30 days to allow the engineer in charge of the project to hand over additional paperwork.
The period in question above includes both the time needed to examine the project for which funding is sought and the time necessary for additional permits to be issued. To this end, the emergency legislation provides for streamlining of procedures regarding repairs to lightly-damaged buildings, equating them to routine maintenance operations. This equation has greatly simplified matters since Italian legislation covering this type of work merely requests that the Municipality receive written notice of commencement without imposing additional formalities. In the specific case of repairing earthquake damage, such notice was replaced by the grant application.

Conversely, as regards more seriously-damaged buildings, the emergency legislation makes no provision for fast tracking, therefore, the grant application must be submitted along with all plans and drawings specified by the current “Consolidated Building Act”, Presidential Decree No. 380/2001.

Where the work entails demolition and reconstruction, the above-mentioned deadlines are extended to allow drafting and approval of the design for the new building, the Act granting an additional 140 days plus 30 days for handing over any additional paperwork.

The detailed analysis of the design enclosed with the grant application included both an assessment of the fairness of the estimate, involving checking the costs specified in the design, and checking the appropriateness of the type of workmanship employed and the work requested.

For every type of structure (reinforced concrete, masonry, industrial buildings), the designs for lightly-damaged buildings call for similar repairs. On the other hand, the designs for more seriously-damaged buildings are far more complex due to both the greater extent of damage and the complex nature of the requested seismic retrofitting. In this respect, it should be noted that Italian technical standards for construction provide for three levels of repair to existing buildings: local repair or reinforcement, restricted to certain structural members; seismic retrofitting that requires a set of operations to change the overall behaviour of the structure and thus increase its safety rating without actually reaching the safety level requested for brand new buildings; earthquake-resistant upgrade that requires a set of operations capable of providing an equivalent safety level to that requested for brand new buildings. The first type of work (local repair or reinforcement) involves surveying the individual structural members requiring repair without the need to quantify the overall improvement in the building’s behaviour; this type of repair regards work that has little or no impact on the distribution of mass and stiffness and therefore little effect on the global behaviour of the building. Examples of such work include reinforcing reinforced-concrete structural members with carbon fibre (typically areas around joints, more rarely entire structural members), improving connections between floors or roofing and the walls of masonry buildings using metal ties and attaching non-structural elements to structures. For buildings with a B or C usability rating, bearing in mind the limited damage caused by the earthquake, the only grant available was for local reinforcement work aimed at strengthening local weaknesses in structural members and mitigating specific local structural and non-structural vulnerability.
The repetitive nature of the proposed work certainly facilitated the process of checking projects for B and C-rated buildings, unlike those for E-rated buildings for which the planned repair work was certainly far more complex and specifically adapted to suit the peculiar characteristics of each individual building. Furthermore, it should be remembered that structural repairs to any building seriously damaged by an earthquake generally require installing brand new or upgrading electrical systems, heating and plumbing in order to comply with current safety and energy-saving regulations. This lengthens the time required to complete design work and that needed to perform the necessary checks.

As regards the effectiveness of the checks carried out, an analysis of the grants approved for seriously-damaged buildings shows that of the amount requested totalling EUR 1,309,801.53, grants were given worth EUR 1,223,500,316.17, amounting to 93.4% of the total amount requested (figures updated to October 2012). The amount not approved for funding therefore totals EUR 86,301,133.76. For comparison purposes, it should be noted that in 2011 the amount paid by the Italian government to the owners of uninhabitable properties in order to provide temporary living accommodation totalled around 40 million euro.

3. Legislation implemented to manage the effects of the Emilia Romagna earthquake

3.1 Legislative changes

In the previous chapter we looked at the merits and limitations of the legislation adopted following the earthquake that struck the Abruzzo region in Central Italy in April 2009. About three years later, in May and June 2012, an earthquake swarm that reached its climax with three events of magnitude ranging from 5.0 to 5.9 Mw struck a large area of Northern Italy, mostly within the boundaries of the Emilia Romagna region. Unlike the 2009 earthquake, the area affected has a low population density, but a high concentration of businesses. The earthquake caused 17 deaths and made around thirty thousand buildings uninhabitable.

In many ways, the legislation implemented for reconstruction following this event is similar to that adopted following the 2009 earthquake in Central Italy, although with various changes aimed at generally speeding up grant approval procedures. More specifically, the following should be noted.

Despite three regions being involved in the 2012 earthquake, Emilia Romagna, Lombardy and Veneto (although the last two to a much lesser extent), unlike the 2009 earthquake, the twin legislative step (Prime Ministerial Ordinances/Government Commissioner Decrees) was eliminated since, as stated above, it had proved very difficult to put into practice. For the 2012 earthquake, following Act 74/2012, the only additional enactments are those by Government Commissioners (one Commissioner per Region who is the Chairman of that Regional Authority). The most important ordinances are issued simultaneously by the three commissioners in joint agreement. Following the 2009 earthquake, in order to regulate certain key aspects of the private reconstruction work, over a period of approx. 2 years, 10 Prime Ministerial Ordinances (Nos. 3778, 3779, 3790, 3803, 3805, 3820, 3832, 3881, 3897,
were issued in addition to various Prime Ministerial Ordinances, Decrees and Circulars concerning secondary aspects. 6 months after the earthquake in Emilia Romagna, just three Ordinances have been issued (29, 51, 57), so far amended three times by additional corrective Ordinances.

The building safety rating is issued immediately after the main seismic event (surveys usually commence a few days afterwards) with a relatively short amount of time set aside for each property visited and it should be noted that inspections take place under difficult conditions due to the prevailing state of emergency. Further misunderstandings may arise if the maps utilised are not up to date or drafted accurately. This means there may be errors in assigning the safety rating that generally lead to a second survey being necessary. In the event of problems, the repeat survey or, in any event, the safety rating of damaged buildings that in 2009 called into play some extremely muddled procedures, has been simplified with a complete rewrite of the procedures for correcting multiple or incorrect ratings.

As part of the funding available, the 2009 legislation set aside specific funds for carrying out improvements to the damaged building. In particular, there were grants for the partial or total cost of work for improving the building’s resistance to seismic actions, energy saving, making systems compliant with current safety legislation and the removal of architectural barriers. The introduction of specific limits for each of the types of work listed above was notably restricted, thus making it simpler to prepare the bill of quantities and conduct checks. This has also allowed designers to deal more easily with the specific conditions typical of every damaged building.

In the case of buildings like blocks of flats with more than one owner, the 2009 legislation called for the submission of a grant application by every owner affected and a further application by the property manager for communal areas. Therefore, for a block of flats with "n" different owners, the number of grant applications could be as many as n+1, thus placing those processing the applications under considerable pressure. On the other hand, the legislation implemented in 2012 simply calls for a single grant application to be submitted by the property manager. Multiple grant applications from every owner are no longer necessary and the division of the funds received between the various owners is merely recorded in the block’s accounts. This simple amendment enables a notable reduction in the number of grant applications submitted for each building (on average 75%), making it much easier to process the applications received.

3.2 Demolition and new construction

In addition to several old town centres, including buildings of notable value, the 2009 earthquake also struck densely-populated suburbs, including reinforced-concrete buildings mostly constructed immediately after the Second World War. By introducing the feasibility limit with the enactment of Prime Ministerial Ordinance 3881, the legislator has shown that it can be more economically viable to demolish and rebuild damaged buildings rather than repair them. Such possibility was provided for by Prime Ministerial Ordinance 3881 enacted in 2010, about one year after the seismic event; however, the practical effects of said Prime
Ministerial Ordinance were postponed for several months until certain necessary implementing provisions were published. The 2009 reconstruction Act was the first to make express provision for owners to be offered the possibility of demolishing and building a new property should they see fit, even without exceeding the feasibility limit. The possibility of demolishing and reconstructing damaged buildings rather than repairing them, with the owner adding his own contribution to the Government grant, has not proved very popular. This is due to both the legislative delay and the information given to the public that was probably not very clear.

The legislation implemented following the 2012 earthquake is not yet complete at the time of writing this paper and currently fails to mirror the provisions of the previous 2009 Act.

4. Conclusions

Following the 2009 earthquake that struck Central Italy, legislation covering the reconstruction of private buildings was completely rewritten. In little more than three years, funding has been provided for around 22,000 sites, compared to around 27,000 grant applications. In the above-mentioned legislation, we can find plenty of pluses, but also several shortcomings, the latter being partly mitigated by the subsequent Act regarding the earthquake that struck Northern Italy in 2012 that has yet to be fully implemented. The difficulties that have emerged in dealing with the effects of the 2009 and 2012 earthquakes and the different ways in which they have been handled highlight all the limitations of the current Italian regulatory framework for managing post-emergency situations. In particular, there is no specific regulatory framework to provide guidance with regard to reconstruction and the return to normality following a disaster. This study provides a basis for drafting a new comprehensive law for post-earthquake measures. The aim is to establish a set of certain rules which can be applied to all large-scale seismic events. Regulatory certainty may promote greater use of insurance policies and operations to reinforce structures during scheduled maintenance work on the buildings.

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Assessing Regulatory Framework Efficacy for Seismic Retrofit Implementation in New Zealand

Temitope Egbelakin

Abstract

Seismic retrofitting of earthquake-prone buildings has been a major challenge in many seismically active countries, including New Zealand. Earthquake losses can be minimised through the formulation and implementation of relevant regulatory frameworks such as policies, building codes and legislation. The recent Christchurch earthquakes have demonstrated the vulnerability of the New Zealand built environment to earthquake disasters, which suggest that existing regulatory frameworks may have been ineffective to reduce the impact of large earthquake disasters.

This paper examines the efficacy of existing regulatory frameworks in mitigating the risk posed by earthquake disasters to the community as whole. The multiple case study approach adopted in this paper, revealed significant barriers posed by the New Zealand Building Act and Territorial Authorities (TA) or local councils earthquake-prone policies, to seismic retrofitting of vulnerable buildings. These barriers include the seismic design philosophy and minimum strengthening requirements of the Building Act, timeframes allowed for strengthening and the lack of mandatory disclosure of seismic risks in TA policies. The research findings offer new insights into the impact of expert-driven regulatory frameworks on earthquake risk mitigation, and suggest a reappraisal of the some of the Act’s provisions and the policy implementation approach adopted by various local TA.

Keywords: Efficacy, Seismic Retrofitting, Earthquake-prone Buildings (EPBs), Building Act (2004), Earthquake Policies, Territorial Authorities (TA)
1. Introduction

The severity of past earthquake disasters has demonstrated the vulnerability of various communities, including in New Zealand to disastrous seismic events. Earthquake-related regulations such as policies, building codes and legislation are significant for disaster risk mitigation because property owners are mandated by these legislative frameworks to adopt mitigation measures (Burby and May, 1999). The New Zealand government enacted legislation in the Building Act (2004) and developed a building code, various building standards and policies, with the objective of reducing the level of earthquake vulnerability of the public. However, the recent Christchurch earthquakes caused significant widespread damage to buildings and infrastructure, 185 deaths, various causalities and a US$22 billion financial loss (Vervaeck and Daniell, 2011). Many unreinforced masonry buildings (URM) or parts of buildings collapsed and various modern building structures were critically damaged. 80 percent of the people who died from the earthquake disaster were members of the public, including pedestrians and motorists who were outside the collapsed or damaged buildings (Canterbury Earthquakes Royal Commission (CERC), 2012). This high percentage of fatality demonstrates that unstrengthen earthquake-prone buildings (EPBs) do not solely constitute a risk for the building owner or occupants but the whole community. These devastating impacts suggest that existing earthquake-related regulatory frameworks may be ineffective for ensuring public safety and recovery from a major earthquake event. The subsequent section provides an overview of New Zealand’s earthquake mitigation policy and implementation process, to offer insights on seismic retrofitting of EPBs.

2. Seismic Retrofit Implementation in New Zealand

In New Zealand, compliance with earthquake-related regulations is mandatory. The Building Act (2004) recommended a seismic retrofit level of 33% of the code requirement for a new building, referred to as the New Building Standard (NBS), by targeting the most vulnerable buildings. This 33% NBS represents the minimum requirement necessary for ensuring safety in an earthquake event. A building having a structural seismic performance score less than 33% NBS is regarded as a high-risk building, a score greater than 33% NBS indicates a moderate risk, while 67% NBS or more is not considered a significant risk. However, 67% of the NBS was considered as a more suitable minimum seismic retrofit level because the Act’s minimum requirement was found inadequate to eliminate the non-ductile failure mechanisms found in EPBs (New Zealand Society for Earthquake Engineering, 2006). Therefore, the New Zealand Society for Earthquake Engineering (NZSEE) considered a score of 67% NBS as a more suitable minimum level (New Zealand Society for Earthquake Engineering, 2006). Likewise, the Act stipulates that an existing building that requires alteration or a change of use must comply with the building code in the same manner as a new building (Sections 112-113). In compliance with the Act’s regulations, seismic rehabilitation of EPBs often triggers other building code requirements such as fire performance and disability access. Cost implications due to these triggers often discourage building owners from voluntary seismic mitigation (Egbelakin et al., 2011).

Further, the Act mandates local or territorial authorities (TA) to manage the mitigation of earthquake risks within their jurisdiction by developing and adopting a policy that specifically
addresses seismic risks. The Act allows the TA to determine the seismic strengthening level, policy implementation approach and timelines for strengthening the identified EPBs appropriate to their respective regions (Sections 131-132). Despite the NZSEE’s recommendation of a higher seismic standard, 73% of the TA adopted seismic retrofit levels between 34% and $\leq 67\%$ NBS, while 27% of TA adopted 67% NBS (Department of Building and Housing, 2005). Anecdotal evidence suggests that the retrofit levels adopted by the different jurisdictions relate more to available human and financial resources, political demands and earthquake experience than the region’s seismicity. In addition, the TA could choose a passive, an active or a combined active-passive approach towards implementing their earthquake policy. The active approach includes a rigorous identification and detailed assessment of potential EPBs, followed by either retrofitting or demolishing identified EPBs within a time period of three to ten years. In the passive approach, seismic strengthening is only triggered only by an application for a building alteration, change of use and the extension of the building’s functional life. A total of 45% of the TA chose the active approach, 32% chose the passive approach and 23% chose the combined active-passive approach (Department of Building and Housing, 2005).

Consequences from recent Christchurch earthquakes since September 2010 to date, which include loss of life, property and infrastructure damage, short and long term financial hardship, and disruption to normal social life within the wider community, suggest that the existing regulatory framework such as some of the provisions of the Building Act (2004) and TA policies, designed for earthquake risk mitigation has been ineffective in satisfactorily mitigating earthquake disaster impacts. This study sought to examine the efficacy of the current regulatory framework related to earthquake risk mitigation, and how it affects seismic retrofit implementation of EPBs in New Zealand. Efficacy of earthquake-related policies and legislation as conceptualised in this study, relates to the extent to which the formulation and implementation of these regulations affect earthquake risk mitigation in New Zealand, specifically the strengthening of EPBs. Assessing the efficacy of earthquake-related regulations has been attributed to risks perception, frequency of seismic retrofitting of EPBs, the community’s level of acceptable risks and policy formulation and the implementation approach for treating unacceptable risks (Prater and Lindell, 2000; Comerio, 2004; Burby, 2005; Burby et al., 2006).

3. Research Method

A multiple case study approach as referred to by Yin (2009), was adopted in this study due to the complexity of the research problem and the diversity of the different seismic risk regions in New Zealand. Semi-structured interviews and document analysis were used as the data collection techniques. Interviews allowed the different stakeholders involved in earthquake risk management to describe their experiences in the development and implementation of the relevant regulatory frameworks across different seismic risk regions. The evaluation of relevant regulatory documents highlights some of the constraints placed on the implementation of adequate risk mitigation measures by the existing legislative provisions.
Four cities in New Zealand were chosen as case studies, based on their seismicity, hazard factor, percentage of non-retrofitted and retrofitted EPBs, earthquake probability and likely severity. Similarly, participants were selected through a purposeful sampling procedure based on the research objectives and questions and because it allows the selection of relevant key participants involved in earthquake risk mitigation as the units of analysis (Babbie, 2008). The participants selected include building owners, engineers, architects and managers of governmental organisations that include city councils and territorial authorities (TA). Building owners include both persons who have or have not retrofitted their EPBs and may or have been not involved in recent Christchurch earthquakes. Other participants chosen for the interview have at least a minimum of two years’ recent involvement in EPB retrofitting projects. These participants were selected in order to make use of their practical knowledge and experience to obtain information and gain a better qualitative understanding of the importance of the different aspects of seismic retrofit decisions. The use of multiple cases and the participant selection method ensure that data reliability and internal validity are strengthened. Forty-eight interviews were conducted and transcribed. All interview transcriptions were analysed thematically using NVIVO qualitative data analysis software. Both participants and industry experts reviewed the findings for confirmation and comments, to establish data validity.

4. Findings

Research findings from this study established that current regulatory frameworks, such as the Building Act (2004) and the TA earthquake-prone policies, pose barriers to seismic retrofit implementation in New Zealand. Key results are discussed in the following subsections within the context of the research investigation.


The findings in the current study show that certain provisions of the Building Act (2004) discussed below constitute potential impediments to the seismic strengthening of EPBs and for future pre-earthquake disaster mitigation in New Zealand.

4.1.1 Minimum Requirement for Life Safety

The minimum requirement of the Building Act (2004), as revealed in this study, serves as an impediment to seismic retrofitting of EPBs by building owners. The minimum requirement tolerates damage to the primary structure and to other building elements in the event of a major earthquake. It is apparent that the 151 deaths resulting from the collapse of the CTV building are perhaps an outcome from a rare event that was not anticipated by the Act’s minimum requirement. In addition, hearings from the Canterbury Earthquakes Royal Commission (CERC) investigations suggest that the current minimum does not match the community’s expectation of a building’s performance in an earthquake (CERC, 2012). Moreover, the minimum earthquake performance level adopted by the Act and the differing New Zealand Society for Earthquake Engineering’s (NZSEE) recommendation of a higher seismic performance level for EPBs, has created confusion and misinterpretation amongst building owners and other retrofit stakeholders regarding what retrofit level provides an
optimal result in terms of seismic strength and rehabilitation cost (Egbelakin et al., 2011). Some building owners were found to have adopted the lowest cost-permissible retrofit level without considering the hazard implication of such a structural performance level (Hopkins, 2005). The recent Christchurch earthquakes resulted in enormous losses to both property owners and the country as a whole, which further demonstrates the implications of the Act’s minimum requirement. Although the design of various contemporary buildings within the Christchurch CBD ensured that people could safely vacate them immediately after the earthquake, many buildings were considerably damaged and others needed demolition. Also, the Act’s minimum requirement contributes to the TA’s lack of commitment to earthquake hazard mitigation, which is evident in the implementation approach adopted in their policies, such as lack of public awareness programs and defined timelines for taking action with vulnerable EPBs. Most TA that adopted less than a 50% NBS are unlikely to have proactive risk-reduction programmes, as evidenced in the adopted policies, with 27% of the TA not specifying timeframes for strengthening identified EPBs, and 31% of the TA having no public awareness programmes to promote mitigation within their jurisdictions (Department of Building and Housing, 2005).

4.1.2 Change of Use Conditions

In compliance with the Act’s regulations in sections 112 and 115, seismic rehabilitation of EPBs often triggers other building code requirements, such as fire performance and disability access. While it is reasonable to support the objectives of these sections, the cost implications of these triggers often discourage building owners from retrofitting their EPBs. There is thus a need for further research to investigate whether such requirements are justified in the interest of public safety and in relation to other relevant public policies. Similarly, Section 112 requires that a building that is altered shall comply structurally or seismically to the same extent as before the alteration. However, the categories of additions are not specifically covered. For example, a building with a score of 40% NBS could potentially be altered, provided that the resulting capacity is still not less than 40% NBS. Findings from this study showed that the implementation of Section 112 has significantly increased the proliferation of substandard structures within the community, leading to a growing level of vulnerability to seismic disaster. This is particularly evident in the number of collapses of masonry structures.

4.1.3 Lack of Mandatory Disclosure of Seismic Risks

Currently, none of the regulatory mechanisms relevant to earthquake risk mitigation in New Zealand specifically address whether the disclosure of building seismic risks should be mandatory or not. A lack of mandatory disclosure limits different stakeholders’ knowledge and awareness of issues related to seismic risk, especially for participants within the property market. Findings from the qualitative study revealed that most of the stakeholders in the market have little or no knowledge about EPBs, seismic retrofit standards, legal obligations and potential liabilities relating to the changes in the Building Act (2004) and TA earthquake policies. Consequently, an insufficient weighting is attached to retrofit costs in investment and purchase decisions by potential buyers and vendors, due to failure to sufficiently account for the seismic rehabilitation costs necessary to strengthen the building,
which results in underinvestment in earthquake risk mitigation. Findings from this study show that mandatory disclosure of a building’s seismic risks in relevant regulatory frameworks and property market transactions is necessary, to improve earthquake risk mitigation in New Zealand. For instance, mandatory risk disclosure would ensure that buyers, insurers and lenders are adequately informed, leading to an informed property market.

4.2 Provisions in Earthquake-Prone Policies (Prepared by the TA)

Some of the provisions of the TA earthquake provisions acting as obstacles to earthquake risk mitigation are discussed in this section.

4.2.1 Policy Implementation Approach

The policy implementation approach adopted by TA has several implications. Some of the TA have good programmes in place to mitigate earthquake hazard and risk, while others have done little, or lack adequate resources to implement mitigation measures. The passive mitigation approach adopted by some of the TA serves as an impediment to earthquake risk mitigation. Likewise, findings from the Christchurch earthquake disasters highlight the ineffectiveness of a TA policy taking a passive implementation approach, and the need to urgently implement consistent policies throughout New Zealand to address the potential threats posed to the community.

4.2.2 Timeframes for Retrofitting EPBs

Timeframes for strengthening EPBs vary widely among TA, ranging from 5-30 years depending on the building type and importance level (DBH, 2005). Most of the TA policies also allow for a possible time extension for strengthening EPBs. In the interim, people still reside and work in these vulnerable buildings and they could be susceptible to risks posed by a future disastrous earthquake. The Christchurch earthquakes provide an example of where longer timeframes impede the adoption of mitigation measures. Effective timeframes for retrofitting EPBs is necessary in TA policies, while considering regional hazard factor, resource availability and effective building life span.

5. Discussion of Findings

Certain provisions of the New Zealand earthquake-related regulatory framework pose difficult challenges for earthquake risk mitigation in New Zealand. Some of these constraints include the seismic design philosophy, minimum requirements of 33% NBS, timeframes, disability access and fire requirements in TA policies. The study findings show that the current approach to seismic design in the New Zealand Building Act (2004) is inadequate to ensure people’s safety and economic recovery after earthquake disasters. Generally, most earthquake-related policies and legislation do not usually specify any applicable performance standards, but set out objectives that must be achieved or recommend minimum safety requirements, such as in the New Zealand Building Act. However, the New Zealand Christchurch earthquakes have demonstrated that such minimum requirements are not economically viable and do not meet the community’s expectations of retrofitting.
buildings only for life safety. Also, financial bail-outs from the Earthquake Commission, central government and private insurance companies are inadequate to cover associated expenses from the disasters. Furthermore, the Act’s minimum requirement affects the TA’s commitment to earthquake risk mitigation, which in most cases will not lead to consistent, strongly implemented, risk-reduction programmes across the medium-to high-risk jurisdictions. This finding is in line with the outcomes from Comerio (2004) and Prater and Lindell’s (2000) research that concluded that the minimum requirements of most building-oriented legislative mechanisms are only intended to ensure public health and safety in an earthquake event, and in most cases would lead to a complete economic loss of the building.

Furthermore, decisions regarding the extent of mitigation programmes to be implemented are left primarily to TA. One outcome of such a model is that some districts have good programmes in place to mitigate earthquake hazards (the active approach such as in Wellington), while other communities have done little or lack adequate resources to implement mitigation measures (the passive approach such as in Lower Hutt and Christchurch). Several statements from the research participants revealed that the model of government in New Zealand indicates that city councils and TA do not receive substantial financial support, if any, from central government for reducing earthquake vulnerability. Evidently, there is a need for central government to provide additional resources to local councils and TA if New Zealand's non-tolerance for EPBs is to be increased.

Mandatory disclosure of seismic risks required by the Building Act (2004) could help improve the seismic rehabilitation of EPBs, as owners or developers would be obligated to disclose their building’s seismic risks to prospective buyers or tenants at the point of sale or rent. For instance, the owner of the CTV building that completely collapsed in the February 2011 earthquake was unaware of the building seismic risks at the time of purchase. There is a possibility that if the CTV owner had been made aware of the extent of the building’s vulnerability to earthquake risks, the cost of retrofitting could have been factored into the investment decision and retrofitting work carried out. Mandatory disclosure of seismic risks would provide a seal on potential EPBs, while communicating more accurate information to the stakeholders. Besides, some of the anomalies, such as lack of access to building risk information and poor risk communication associated with the building safety evaluation processes after the September 2010 earthquake, which contributed to increased disaster losses in the February 2011 earthquake would have been reduced if seismic risks disclosure had been mandatory.

6. Recommendations

Upon the appraisal of current regulatory frameworks and interview findings in four different cities in New Zealand, specific recommendations are presented in relation to the Building Act (2004) and TA earthquake-prone policies. Firstly, there is a need to review the Act’s minimum requirement of 33% NBS for seismic retrofitting of EPBs. It is thus suggested that the earthquake-prone threshold should be increased to 67% NBS, as recommended by the New Zealand Society for Earthquake Engineers (NZSEE) (2006), or adjusted more effectively to accommodate occupancy levels in buildings used for commercial purposes.
Secondly, an appraisal of the policy implementation approach and timeframes adopted by some TA is necessary, to allow TA within low to high-risk zones to adopt an active implementation approach, coupled with proactive public awareness programmes and community engagement in order to improve commitment levels and to achieve consistent earthquake mitigation strategies across their regions. Finally, it is necessary to overlay most of the relevant policies and regulations related to natural hazard management and improved urban planning, such as the Land-use Planning and Resource Management Act (RMA) (1991), Civil Defence Emergency Management Act (2002) and historic preservation and disaster recovery with the seismic strengthening of EPBs, in order to promote earthquake hazard mitigation.

Overall, some of the recent devastating earthquakes, such as in Haiti in 2010, Indonesia in 2004 and also in New Zealand, have demonstrated the ineffectiveness of several earthquake regulatory frameworks devised for reducing disaster impacts. Hence the need to adopt proactive approaches to formulate, adopt and implement an effective mitigation policy. Thus, effective methods for reviewing present policies and regulations are necessary to improve earthquake risk and hazard in seismically active countries.

7. Conclusion

The research findings offer new insights into the impacts of expert-driven regulatory frameworks on earthquake risk mitigation. The Christchurch earthquakes have proven that this approach may not be effective in certain disastrous situations suggesting the need for strategies aimed at adequate pre-disaster mitigation strategies. Hence the need to re-examine the current seismic design philosophy that focuses only on life safety and possibly, the minimum acceptable earthquake-prone hazard level would be adjusted to community expectations of building performance in a seismic event. The findings from this study show that the Building Act and TA earthquake-prone policies would be enhanced by undergoing legislative reforms with regard to matters such as minimum requirements, strengthening targets, implementation approach and timeframes. It is important to acknowledge that seismic risk differs across all parts of New Zealand and such differences should be taken into account when determining the regulatory response for each region. Also, a review and realignment of all regulatory documents is necessary to present a robust framework where New Zealand communities such as Christchurch, can gradually recover after a major earthquake disaster, while planning for pre-disaster mitigation against future earthquakes. The findings suggest some practical changes for policies devised for earthquake risk mitigation, both in New Zealand and other seismically active countries.
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Capacity Building to achieve Sustainable Water Management System in Arid and Semi-Arid Lands (ASALs)

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Abstract

Arid and Semi-Arid Lands (ASALs) comprise of more than 40% of the earth’s land surface and supports 20% of the total human population. Droughts, or periods of unusually low rainfall, are part of the expected pattern of precipitation in these regions. Over the past decade, the effects of climate change have become more pronounced, leading to reoccurring cycles of drought in ASALs. The 2011 drought in the Horn of Africa was considered to be the worst in past 60 years which affected 13.5 million people. Such events had far reaching adverse impacts on human health, food security, economic activity, physical infrastructure, natural resources, environment, and national and global security. In order to improve the situation and mitigate the effects, government and NGOs continue their efforts for capacity building through water interventions and training programs. But these initiatives are often short term and uncoordinated. Therefore, there is a need for a holistic framework for capacity building to achieve a sustainable water management system in ASALs. This paper outlines a framework for capacity building that aims to integrate indigenous water management systems with strategies required to overcome current issues. Main focus of this paper is to illustrate three types of capacities (economic, social and environmental) at three levels (individual, organizational and system) to achieve a sustainable water management system and to present a framework that involves five defined phases of capacity building. These five phases are preparation, assessment, planning, implementation and evaluation. This framework would assist in achieving reliability of long-term water availability and enhance self-reliance over time.


1. Introduction

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Arid and Semi-Arid Lands (ASALs) are characterized by low and erratic precipitation which results in low and unpredictable crop and livestock production. Typically, arid areas are defined as those receiving less than 200 mm of winter rainfall or less than 400 mm of summer rainfall annually (UN Economic and Social Council 2007). Conversely, semi-arid areas are defined as those receiving between 200–500 mm of winter rainfall or between 400–600 mm of summer rainfall (UN Economic and Social Council 2007). The annual rainfall varies between 50-100% in the arid zones of the world with averages of up to 350 mm. In the semi-arid zones, annual rainfall varies between 20–50% with averages of up to 700 mm (UN Economic and Social Council 2007). In Africa, ASALs (excluding deserts or hyper-arid lands) comprise of more than 40% of the land surface (UN Economic and Social Council 2007). Figure-1 shows a large portion of land area in Africa is currently under water stress and water scarcity (FAO 2008).

According to the Falkenmark Water Stress Indicator, a country or region is said to experience "water stress" when annual water supplies drop below 1,700 m$^3$ per person per year. At levels between 1,700 and 1,000 m$^3$ per person per year, periodic or limited water shortages can be expected. When water supplies drop below 1,000 m$^3$ per person per year, the country faces "water scarcity".

![Figure 1. Freshwater availability around the globe (FAO 2008)](image)

Most of the countries in Figure-1 which are under water stress and scarcity have “traditional” or “indigenous” approaches that have been used for managing water scarcity. They are based on lifestyle adaptations that minimized consumption and maximized beneficial local use (Arab Water Council 2008). The natives of these regions have several indigenous coping mechanisms to overcome the effects of drought in these areas. But studies conducted by UNEP in 2008 mentioned a steep decline in use of such knowledge in past few decades. A 2008 report by Arab Water Council also mentioned the dominance of indigenous knowledge up to the 1970s and increase in usage of modern water management practices after 1970. Though these technological innovations help for a short period of time, they significantly alter water management behaviors and create social, economic and environmental disruptions in these ASALs. Deep tube wells allow continual, unsustainable drawdown of aquifers as well as access to fossil water, wherever available. Pumps allow faster abstraction from canals and rivers than...
previously possible, disrupting historical patterns of consumption. Some of the challenges causing these disruptions are short term planning and lack of a framework to build capacity (UNESCO-IICBA 2006). This paper aims towards identifying methods for building capacity to achieve sustainable water management system in ASALs of Africa.

2. Background

There are various definitions of “capacity” and "capacity building”. Sometimes the terms are used in an ambiguous manner or without being defined (UNDP 2008, UNEP 2002). Hence, it is necessary to have a common and clear understanding of basic concepts. UNISDR (2009) defines capacity as, combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. UNDP (2005) defines capacity building as sustainable creation, retention, and utilization of capacity in order to reduce poverty, enhance self-reliance, and improve people’s lives. The term capacity building evolved from past terms such as institutional building and organizational development lead within UN systems for action and thinking (UNDP 2008). In the 1950s and 1960’s these terms referred to community development that focused on enhancing the technological and self-help capacities of individuals in rural areas (UNDP 2008). In the 1970s, following a series of reports on international development, an emphasis was put on building capacity for technical skills in rural areas, and also in the administrative sectors of developing countries where training was the most important activity (UNDP 2008). For a long period of time capacity building was referred to training individuals. In the 1980s the concept of institutional development started expanding even more. In the year 2000, UNDP with its partner strategic GEF Secretariat, launched the Capacity Development Initiative (CDI), which involved extensive process to identify countries’ priority issues in capacity development needs on global environmental issues. Then the three levels of capacity building were developed by UNDP as individual level, organizational level and system level (UNDP 2008). Individual level focused on attitudes and behaviors-imparting knowledge and developing skills of an individual entity while maximizing the benefits of participation, knowledge exchange and ownership (UNDP 2008). Organizational level focused on the overall organizational performance and functioning capabilities, as well as the ability of an organization to adapt to change (UNDP 2008). System level emphasized on the overall policy framework in which individuals and organizations operate and interact with the external environment (UNDP 2008).

In 2005, a German Donor Agency GTZ (Deutsche Gesellschaftfür Technische Zusammenarbeit) introduced the concept of five phases of capacity building cycle. These five phases were: preparation, analysis, planning, implementation and evaluation. Phase I is the preparatory phase of the capacity building cycle which addresses the agreement on objectives, the establishment of the work process at the individual, organizational and system levels. Phase II identifies existing capacity gaps in view of particular goal which has to be achieved. It determines capacities which need to be built, acquired or utilized. Phase III transforms identified capacity needs into time dependent capacity building strategies. Phase IV is implementation of activities that requires sound planning of measures and identification of capacity building service
providers to deliver specific services. Phase V is the final phase that evaluates the impact of capacity building (GTZ 2005).

Capacity building has evolved a lot in past decades but the 2005 report by World Bank Operations Evaluation Department, mentioned that capacity building was still not a well-defined practice in ASALs of Africa. Herold’s 2009 report on water crisis in Africa mentioned that capacity building for water management has several challenges in almost all the ASALs in Africa. Various challenges mentioned in his report were:

- Immediate needs are addressed instead of long term planning. Capacity building caters to immediate water needs that creates mismatch between water supply and water demand grows in few years. Also as mentioned in the UNEP 2002 report, water demand calculations conducted in past took care of the immediate needs of water demand or need in near future thus if there is a drastic change in the future demand, the availability of water is not enough to cater the community.
- Absence of a capacity building framework. Different policies related to water securities and usage are not defined in usual water management programs and absence of these capacities lead to theft of water and over exploitation of water resources (UNESCO-IICBA 2006. Most of the communities in ASALs of Africa are poor and live a nomadic life, traveling with their livestock in search of water and pasture (FAO 2008). There is no legal administration regarding water security policies in those regions (UNEP 2002). Thus water theft arises purely from failure to define water rights, enforce monitoring, lack of interpretation of readily available information that is collected at great cost and enforce compliance.
- Several agencies understand capacity building as a post disaster need assessment programs whereas some believe that capacity building is limited to training people and organizations living in different communities (World Bank OED 2005).
- Decline in indigenous knowledge and its application is one of the biggest capacity building challenges in rural areas of ASALs of Africa (UNEP 2008, Arab Water Council 2008). Capacity building needs a lot of community interaction and involvement, indigenous skills, customs and social norms help the better involvement of pastoral communities in ASALs.
- Capacity building is always performed to achieve agreed goals but often the goals are not clearly defined.
- Unavailability of local authority and legal framework. Capacity building is a long term process and thus it is important to understand the different capacities which need to be developed in order to achieve the goal.

Thus these challenges clearly define the necessity of a capacity building framework for an agreed goal, i.e., to achieve sustainable water management system in ASALs of Africa. There is a need to revive indigenous water management practices with strategies to overcome these challenges. This can be done by using the capacity building framework and understanding the underlying importance of indigenous knowledge for efficient use of resources and the ability to deliver social, cultural and economic needs of the community. This would increase reliability of
long-term water availability in ASALs of Africa and have a potential impact on social, economic and environmental condition of such regions. This paper presents a capacity building framework to achieve sustainable water management system in ASALs of Africa.

3. Research Methodology

Research methodology can be divided in three tasks. (i) Various indigenous water management practices in ASALs around the globe were identified from existing literature as well as the evolution of capacity building was identified. (ii) Second task focused on developing the entire capacity building framework which includes feasibility study of the various indigenous water management practices, selection of a practice to define the goal of capacity building, five phases of capacity building and development of a system dynamic model for a long term projection and sustainable retention of water. (iii) Third task included application of the framework, results and analysis. This paper illustrates the development of the framework whereas application of this framework is subject of another paper.

4. Development of the framework

A generic flowchart of the framework is shown in Figure-2.

![Figure 2. A generic flowchart of the capacity building framework (Sinha 2012)](image)

4.1. Goal: Sustainable water management system

A Sustainable water management system in this research is defined as a system that utilizes rain water harvesting technique to store water using a selected indigenous water management practice. This system addresses the current issues of water management in ASALs of Africa in terms of water security and water usage policies, financial constraints related to construction and maintenance of the system, and legal framework to implement those policies. A capacity matrix is proposed in this research to be utilized during the first four phases of capacity building.

4.2. Feasibility study
Table 1 shows feasibility study of some of the indigenous water management practices selected to be studied for this research based on their cost of construction, water contamination and loss of water due to evaporation. 2004 SASOL report mentions that these three parameters are important technical criteria before selecting any water intervention in ASALs.

**Table 1. Feasibility Study of various indigenous water management practices**

<table>
<thead>
<tr>
<th>Practice</th>
<th>Definition</th>
<th>Cost (USD/m³)</th>
<th>Contamination</th>
<th>Evaporation loss</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roof catchment Systems</strong></td>
<td>Rooftop catchment systems collect rainwater from the roofs of houses, schools, etc., using gutters and downpipes and then store it in containers that range from simple pots to large ferrocement tanks. It is practiced around the globe.</td>
<td>7-15 depending on the type of construction material for container</td>
<td>Low contamination. Very close to portable drinking water</td>
<td>Evaporation loss of water is low in a covered container</td>
</tr>
<tr>
<td><strong>Ponds and Pans</strong></td>
<td>Ponds and pans are like a hole dug in the ground, which can be square, rectangular or round. Very common practice in ASALs of Africa and Asia</td>
<td>30-130 depending on the type of construction material and design of pond</td>
<td>In absence of a silt trap, water in ponds and pans have high contamination</td>
<td>Evaporation loss of water is high</td>
</tr>
<tr>
<td><strong>Underground Tanks</strong></td>
<td>Some communities in ASALs of Africa, Asia and Middle East also direct runoff water into an underground tank or cisterns dug into the ground.</td>
<td>10-150 depending on the type of construction material and design of tank</td>
<td>Contamination is low in a covered underground tank</td>
<td>Evaporation loss is low in covered underground tank</td>
</tr>
<tr>
<td><strong>Johad</strong></td>
<td>Johads are simple mud and rubble barriers built across the contour of a slope to arrest rainwater. It is primarily used in ASALs of India.</td>
<td>1-4 depending on the design</td>
<td>Relatively high water contamination</td>
<td>Evaporation loss is high</td>
</tr>
<tr>
<td><strong>Sand dam</strong></td>
<td>A sand storage dam(Or sand dam) is a small dam build on and into the riverbed of a seasonal sand river. Practiced primarily in Ethiopia and Kenya</td>
<td>0.8-2 depending on construction material</td>
<td>Low water contamination due to sand that acts as a filter</td>
<td>Evaporation loss is almost negligible</td>
</tr>
</tbody>
</table>

4.3. Selection
As evident from table 1, among all the practices, sand dam is the least expensive water management practice which stores water within the sandy riverbed causing low contamination as well as almost negligible water loss due to evaporation. Thus in this research, sand dam is selected as the water storage component of the sustainable water management system.

4.4. Capacity Building

It is understood from the evolution of capacity building that it occurs at three different levels (individual, organization and system). But capacity building initiatives still lack a framework that differentiates in various types of capacities such as social capacity, economic capacity and environmental capacity. Hence a capacity matrix is proposed in this paper which includes not only the levels of capacity but segregates them as social, economic and environmental capacity. UNISDR (2009) defines capacity as, combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve the agreed goals. Following the same definition in this research; social capacities are defined as those strengths, attributes and resources which are defined under social parameters related to health, education, resource management, population etc. Economic capacities are those strengths, attributes and resources related to funds and financing and Environmental capacities are those strengths, attributes and resources available within a community, related to environment e.g. river, topography, environment protection policy, environment protection activity etc.

Capacity building is a five phase (preparation, analysis, planning, implementation and evaluation) cyclic activity. In this research the proposed matrix is utilized in the first four phases of capacity building and for the last phase which is the evaluation phase a system dynamic model is proposed to show the water projection as a result of this sustainable water management system.

![Figure 3. Capacity building phases](image)

4.4.1. Phase I Preparation

The preparatory phase of the capacity building cycle addresses the agreement on objectives and the establishment of the capacities required to achieve the objective at the individual, organizational and system levels depending on different capacity types. The objective of this
phase is to prepare for and set in motion a structured process of discussing each capacity required at each level to achieve the goal. In this research, the agreed objective of capacity building is sustainable water management system which includes construction of sand dam and other capacities including policies and resources. Table 2 demonstrates the preparation of the capacities using the proposed capacity matrix.

Table 2. Preparation phase capacity matrix

<table>
<thead>
<tr>
<th>System level</th>
<th>Social Capacity</th>
<th>Economic Capacity</th>
<th>Environmental Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water security policies</td>
<td>Government funds</td>
<td>Topography, Sandy Riverbed</td>
</tr>
<tr>
<td>Organizational level</td>
<td>Local committee, NGOs, Materials</td>
<td>Committee funds</td>
<td>Environment protection agencies</td>
</tr>
<tr>
<td>Individual level</td>
<td>Labors, Skill</td>
<td>Livelihood</td>
<td>Environment protection activities</td>
</tr>
</tbody>
</table>

4.4.2. Phase II Analysis

Second phase of the capacity building cycle is the analysis phase which identifies capacity needs of a community based on a simple scale developed in this research. It identifies the capacities which are available, unavailable or have a limited availability. Unavailability shows that the respective capacity is not available and needs to be created or acquired in order to achieve the goal. Limited availability shows that the capacity is available but needs improvement to achieve the goal. Availability shows that these capacities are available within a community to achieve the goal. Thus for all the capacities mentioned in preparation phase to achieve the goal, capacity need assessment is conducted in analysis phase, using the mentioned scale.

4.4.3. Phase III Planning

The planning phase transforms the identified capacity building needs into time dependent capacity development strategies. Short term and long term capacity building action plan is accompanied by a list of activities in implementation phase to provide strategic direction for capacity building process in the future. Short term action plan focuses on those capacities in each capacity type which need to be either improved or acquired or created in a few months before or during the construction of sand dam, e.g., improvement of individual skill (social capacity at individual level) and selection of a riverbed (an environmental capacity at system level) are some of the capacity building activities which fall under a short term action plan. Long term action plan includes the rest of the limited available and not available capacities, which
cannot be developed immediately and needs to be developed over a year or more to achieve the goal, e.g., water security, financing opportunities and environmental protection policies (all three capacity types at system level).

4.4.4. **Phase IV Implementation**

Once the capacities are divided under short term and long term action plan, implementation schemas are prepared accordingly. The implementation of capacity building activities requires sound planning of measures and the identification of capacity building service providers to deliver specific services. The implementation of capacity building hence includes several types of activities geared towards each type of capacity at different levels. A continuous monitoring of accomplishments ensures that the capacity building process stays on track and that improved governance related products and services are made available to regional beneficiaries.

4.4.5. **Phase V Evaluation**

*Figure 4. Schematic diagram to show causal relationship for part 1*

The final phase of the capacity building process deals with the evaluation of overall outcomes and impacts obtained from capacity building and the goal achieved for the community. Following the implementation of planned capacity building measures, the outcomes and impacts need to be evaluated pertaining to the achieved goal and the impact on social, economic and environmental condition from a sustainable water management system. Thus a system dynamics model is proposed in this research. A system dynamics model helps in understanding the behavior of a complex system over time. Since water management in this research comprises of a complex set of physical and social systems hence system dynamics is used to develop a model to understand water demand and supply after the construction of sand dam. The model also helps in understanding the potential impact of water on social, economic and environmental conditions in ASALs of Africa. The model has two parts:

First part calculates the total water accumulated from surface water of the river bed and the water that is stored in sand dams after its construction. Before developing the model, present
water yield, water demand and total number of sand dams required to be built in a community needs to be calculated.

Three main parameters of the first part are surface water capacity of river, water into sand dam and total water available. The schematic diagram shown in Figure-4 depicts the inflows and the outflows of the three main parameters. Total water resource is the water consumed from surface of the river and from water in the sand dam. This water is consumed by humans, livestock and other facilities like hospitals, schools etc. Water on the surface of the river bed is received directly from rainfall and indirectly from runoffs and this water is lost through evaporation, evapotranspiration, overflow and a portion that goes into the sand dam. Similarly water into the sand dam comes from river surface and the outflow is either for underground recharge or a minimal evaporation loss.

Second part calculates the growth in human and livestock population due to direct impact of water availability. The causal loop for human population and livestock population is shown in Figure-5.

Figure 5. Schematic diagram to show causal relationship for part 2

In Figure-5, first two loops show that increase in total water resource decreases mortality rate and migration rate of human which increases the population which in turn increases the water demand, further increasing the water consumption which reduces the total water resource. The lower loop shows that increase in total water resource decreases livestock mortality rate which increases the livestock population which in turn increases the livestock water demand, increasing their water consumption which reduces the total water resource.

5. Results
The model was run to show a projection for 10 years for a hypothetical case where the total water demand from livestock, human and other facilities for a community was assumed to be 30,000 m$^3$/month (based on the literature review of ASALs in Africa) with an annual rainfall of 200 mm, mean annual rainfall of 2240 mm, evaporation runoff coefficient 70%. For the sand dam, available data saturation of sand dam is 45% of the volume of sand and total extracted water from sand dam was 35% (www.sanddam.org, last visited Nov 2012). The initial water in the riverbed was assumed to be zero as sand dams are built on perennial rivers and total number of sand dam was assumed to be 34.

The result (Figure-6) for this hypothetical case initially shows a decrease in total water resource (as the sand dam becomes fully functional in 20 months (Nissen-Petersen, 2006)), but after that it shows an increase in water availability which starts declining after end of 5th year, primarily because of the growth in water demand but even after 10 years with growth in population and other consumption, water is available; whereas during the past decade several regions in ASALs of Africa got water only during the rainy seasons.

![Figure 6. Results for total water resource (m$^3$) for next 10 years](image)

6. Discussions and Conclusion

Indigenous knowledge for disaster management has helped various communities in Africa to survive in harmony with their environment but a decline in such knowledge is making these communities vulnerable to events like drought. The main aim of this paper was to develop a framework for capacity building to achieve sustainable water management system in ASALs of Africa. This sustainable water management system includes reviving an indigenous water management practice of ASALs of Africa such as sand dams and developing planned strategies for using the water efficiently for long term through capacity building framework. Capacity matrix proposed in this paper highlights different types of capacity along with the three levels of capacity which helps in understanding the importance of social, economic and environmental capacities. This matrix is used in preparation phase, analysis phase, planning phase and implementation phase of capacity building. For the evaluation phase of capacity building cycle a system dynamics model is developed that shows increase in reliability of water availability, using a hypothetical case for the base run of the model.

This framework would mainly assist government agencies and NGOs in their water management interventions in Kenya, Ethiopia and other ASALs in Africa with similar kind of disaster events and climatic conditions. This research helps in understanding capacities in form
of a complex matrix which can be used for achieving agreed goals of a community and is not limited to water management. The system dynamics model proposed in this research helps in understanding the continuous relationship between the demand and supply of water in any region and potential impacts of water availability.

References


Cities and Flooding: Lessons in resilience from case studies of integrated urban flood risk management

Jessica Lamond¹, Zuzana Stanton-Geddes², Robin Bloch³, David Proverbs⁴

Abstract

Flooding can cause disruption and devastation in cities, with massive damage to livelihoods, property and urban infrastructure as recently experienced in New York City, Jakarta, Bangkok, Accra, Mississippi and Queensland. For cities in developing nations, unplanned urban expansion, poor infrastructure and services, inadequate drainage and weak institutional capacity can multiply the negative impact of flooding. In such circumstances, floods often affect informal settlements and bring the additional burden of diverting resources away from poverty alleviation and other development efforts. Preparing for future floods, which may become more frequent in the future, integrated flood risk management recognises that risk reduction which relies solely on engineered defences may be uneconomic, impractical or make flood risk worse under certain circumstances. Therefore authors advocate for a holistic and forward-looking approach to improve resilience of cities in which appropriate engineered measures are combined with non-structural mechanisms, land use planning, emergency preparedness and recovery planning. Decision-makers can use this approach as guidance in implementing balanced and robust solutions in flood risk management.

Funded by the World Bank / Global Facility for Disaster Reduction and Recovery (GFDRR), the flagship report ‘Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century’ was designed to provide operational assistance to policymakers and technical specialists, particularly in the rapidly expanding cities and towns of the developing world, on how best to manage the risk of floods. Comprehensively dealing with available structural and non-structural measures, the handbook provides common guiding principles to building resilience to urban flooding. Over 50 case studies, carefully selected from extensive literature review, workshops and consultations, illustrate current practice, challenges, and lessons learnt from around the world. International and local workshops were held to test and disseminate the key findings and recommendations. A major objective of the research project was to develop a set of policy principles and practical recommendations, based on the case studies, literature and inputs from expert participants at the workshops, to support the implementation of integrated flood risk management through a structured, iterative and participatory process.

Keywords: Resilience, Adaptive Capacity, Urban Flood Management.

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1. Introduction

Flooding poses a serious and frequent risk that challenges the lives of citizens of many major cities around the world (Jha et al., 2011). Direct, rather than indirect, impact from major flood events, as witnessed for example in New York City, Lagos, Pakistan, Mississippi and Australia, are often thought to represent the biggest risk to life and property (Department for International Development, 2005). However, indirect and often long-term effects, such as disease; reduced nutrition; disrupted education; and loss of livelihoods, can have pernicious long-term effects, eroding community resilience and other development goals (UN Habitat, 2010b). In addition to large-scale events, minor and regular flooding can be equally difficult to cope with and detrimental in the long-term. While they are hard to immediately identify and quantify, evidence shows that the poor and disadvantaged suffer the most from long-term effects of flooding (Cannon, 2000, Dodman et al., 2009, World Bank, 2012).

Urban development, rapid growth and increased density of cities are trends implicated in both the increased frequency of flooding and the higher impact associated with urban floods (Jha et al., 2011). The reduced permeability of landscapes associated with urbanisation increases run-off and reduces the capacity of natural floodplains to quickly absorb flows. Higher levels of development expose more people and assets to flood hazard. Rapid urban expansion, which typically takes place without following structured or agreed land use development plans and regulations, makes unsustainable conditions even more problematic. In addition, the urban poor are often excluded from the formal economy, and lack access to adequate basic services. Because of limited resources, and often rights, they tend to be located in densely populated informal settlements (UN Habitat, 2010b).

In response to these challenges, the World Bank handbook for integrated flood risk management was conceived to give guidance in the design and implementation of holistic flood risk management measures that can reduce risk and increase resilience of cities to flood risk challenges in the 21st Century. The handbook incorporated a collection of case studies that informed the development of key principles for integrated flood management. More than 50 examples are used throughout the guide to illustrate particular aspects of integrated flood risk management strategy and systems. While it is impossible to entirely eliminate flooding from cities, the integrated flood risk management approach helps decision-makers and specialists to reduce the vulnerability, manage residual risks, and increase the resilience of the built environment to flood hazard. This paper focuses on the link between integrated flood risk management and improving resilience in cities. The following sections describe the concept of flood resilience within four “capacities”.

2. Concepts of resilience and capacity

Resilience is a contested concept that has gained prominence in the disaster management community over the last decade (Tierney and Bruneau, 2007). The multidisciplinary nature of the disaster management profession ensures that the definitions and concepts of disciplines as wide apart as engineering, finance, ecology and psychology have contributed to the debate around what truly constitutes a resilient environment (Folke et al., 2002, Gallopín, 2006, Institution of Civil Engineers, 2008, Defra/Environment Agency, 2011).
Narrow definitions of resilience, owing their heritage to engineering and from the Latin “resilior”, which means to “jump back”, usually encompass the ability to return back into shape after being affected by external shock (Plodinec, 2009). The shock absorber or “sponge” concept that is the direct opposite of vulnerability (IPCC, 2001) is the root of the definition of building resilience (wet-proofing) where the acceptance of water into a property is mitigated by the use of techniques and materials that will suffer little damage from contact with flood water or are easily removed, cleaned or replaced (Wingfield et al., 2005). Within this definition of resilience, the construction of flood resistant housing can also be considered a resilience measure, as it reduces damage and allows the city to recover more quickly.

In the context of disaster risk management, the definition of resilience increasingly focuses on community resilience and is shifting towards terminology borrowed from ecology and social sciences. Adger (2000) for example defines social resilience specifically as relating to a community’s ability to withstand external social, economic, and political shocks. Bruneau et al (2003) offer the definition that resilience is “the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future disasters.” Whilst Zhou et al (2010) more narrowly refers to “the capacity of hazard-affected bodies (HABs) to resist loss during disaster and to regenerate and reorganize after disaster in a specific area in a given period”. Conversely, Pelling (2003), has a broader definition that “Resiliency is thought of as a characteristic of systems that offers flexibility and scope for adaptation whilst maintaining certain core functions (for example, access to basic needs and social stability)”. The definition holds, at its core, the notion that the state of normality post disaster need not be recognisably similar to the pre disaster normality and emphasises the role of adaptation in the complex evolving system of a modern city. Adger et al (2004) posit that a key concept of the resilience of systems is the potential for self-organisation or spontaneous response as opposed to responses imposed by external forces. This implies risk reduction approaches that are people centred and react to local knowledge, and therefore research on resilience needs to understand how communities and individuals survive and cope with disasters.

Increased resilience is also linked to vulnerability reduction although the relationship between vulnerability and resilience is not easy to specify (Adger, 2006). Using the broader definitions of resilience implies that many measures that reduce vulnerability can also be said to increase resilience and this may be reflected in the strengthening of four capacities within the built environment namely: threshold, coping, recovery and adaptive capacity. In the context of managing flood risk, threshold capacity is the level to which flood hazard must reach before damage and disruption is widespread. Coping capacity reflects the ability of cities to continue to function despite the threshold capacity being exceeded. Recovery capacity is related to the speed and effectiveness of the return to normal operations of the city after a flood; while adaptive capacity denotes an ability to use the recovery period and the time between events to enhance the other three capacities (De Graaf, 2008). Adaptive capacity is central to the broad concept of resilience adopted in this paper. However, while increased resilience results from decreased vulnerability of people and assets it may also result from a general adaptability or coping ability and underlying socio-economic and political factors quite divorced from the flood hazard.
The focus on resilience in flood management shifts the balance of risk reduction within cities from measures perpetrated by authorities to a more collective approach (The World Bank and the United Nations, 2010). As a consequence a coherent, locally-specific and integrated response is needed. The increased resilience of cities therefore requires structural changes to reduce the expected damage from flooding to be balanced with non-structural adaptations directly related to flood management and urban management mechanisms that strengthen the underlying ability of the population and built environment to accept and adapt to change.

Particularly in rapidly developing countries, urban authorities need to address the issues of infrastructure and urban expansion if they want to increase resilience. The broadening of flood risk reduction measures might also affect the clarity in the ownership and perceived responsibility to manage flood risk (De Graaf, 2008), which is why clear institutional arrangements and coordination among the key actors is vital. Flood management can hugely benefit from the involvement of all stakeholders to increase the collective resilience of a city.

3. Strengthening the capacity for resilience: case study examples

As indicated in the section above, resilience of cities can be enhanced by measures that reduced the vulnerability of individuals and communities to flood risk. Selected case studies, included in the World Bank handbook, illustrate how one or more of the four capacities can be strengthened. The case studies were carefully chosen based on a systematic review of relevant literature and examples suggested in consultations and workshops. The selected collection, reaching across Africa (e.g. Ghana, Mali, Mozambique, Senegal, Somalia, Togo, Tunisia, Zambia), East Asia and the Pacific (e.g. Australia, Cambodia, China, Japan, Malaysia, the Mekong region, Micronesia, the Philippines, Samoa, South Korea, Thailand, Vietnam), Southeast Asia (e.g. Afghanistan, Bangladesh, India, Nepal, Pakistan), South America (e.g. Argentina, Brazil, Colombia, Mexico), North America (Canada, the U.S.) and Europe (e.g. France, Germany, Poland, the UK), represents different flood types, geographies, socio-economic variables, city sizes and flood risk measures. A quantitative evaluation of such a diverse body of examples would be limited as the flood circumstances and outcomes were complex and varied, hence a qualitative method was applied.

3.1 Threshold Capacity

Threshold capacity can be increased by many structural alterations to the fabric of a city (Barker, 2011). Some of these measures are the traditional structural changes to the buildings and infrastructure such as raising of buildings (Lamond and Proverbs, 2009) and engineered protection of critical infrastructure (Fankhauser et al., 1999, Kidd, 2011). Increasingly, careful land use planning and regulation, are recognized to be able to reduce the flows associated with a given weather event, while at the same time direct populations out of hazardous areas (APFM, 2007). Furthermore, the implementation of effective and sustainable urban drainage can be employed to absorb flows avoiding damages and losses (Charlesworth and Warwick, 2011).

The following example illustrates plans in New York City to improve the use of urban drainage to control stormwater runoff while decreasing the impact of severe weather by
raising the storm threshold. The New York City Green Infrastructure Program, which forms part of the Green Infrastructure Plan of the Department of Environmental Protection (DEP), introduced new regulations and guidance on the design of stormwater management for new development (NYC Environmental Protection, 2012). The program creates incentives for green infrastructure projects including green-roofing and creating porous paving by property owners, businesses, and community organizations eligible for the funding. The aim was to improve the water quality of the city’s waterways while reducing sewer overflows and flooding. Several demonstration projects have been constructed to show the benefits in practice including blue and green roofs at schools and rain gardens in public open spaces (NYC Environmental Protection, 2011). Initial assessments indicate that green infrastructure has the potential to be cost-effective as there are multiple benefits for the infrastructure over and above the reduction in flood risk. The success of the initiative will depend on the sustained support from local communities and businesses. To ensure this, the City has formed a Citizen’s Group and steering committee from professional stakeholders and other integral communities. The latest update indicates that approximately US$3.8 million has been awarded to local organizations and private property owners engaged in these resilience activities (NYC Environmental Protection, 2011).

3.2 Coping Capacity

Coping with flood events includes structural and non-structural measures such as: early warning and evacuation (Evans, 2011); emergency planning (Emergency Management Australia, 2000); business continuity plans, and temporary flood barriers and shelters (Jha et al., 2012). Valuable lessons in resilience can be drawn from grassroots experiences of dealing with hazards. Understanding local responses can contribute to the strengthening of planning strategies for adaptation to climate change and variability in cities, and avoid situations when imposed solutions do not fit local conditions and customs.

For example, Dhaka, the capital of Bangladesh with over 10 million inhabitants, is central to Bangladesh’s economy. Having experienced nine major floods in the last 55 years and frequent smaller events (Jabeen et al., 2010), the country and city are highly susceptible to flooding. Large areas of the city are only a few metres above the sea level (Dodman et al., 2009). Karail, the largest informal settlement of roughly 100,000 inhabitants, has large areas in the lowest-lying regions and hit by regular inundation. A vulnerability survey carried out by the Development Planning Unit at University College London (UCL) in co-operation with BRAC University in Bangladesh, examined household and collective adaptation strategies to cope with existing environmental hazards (Jabeen et al., 2010). Research indicates that that local coping strategies, that have been adopted either at the household or community level to reduce vulnerability, include physical modifications to the buildings, savings and access to credit, diversified income sources, strong social networks and accumulation of assets. Findings show that the circumstances of living in informal settlements led to the tendency for families to resist evacuation during and after flooding for fear of permanent displacement. Authorities should therefore consider a mix of measures that support the existing local strategy of rebuilding from savings and accumulated assets through risk transfer and micro-finance mechanisms while considering long-term poverty reduction, secure resettlement, and security of tenure to address both flood risk and wider development goals.
3.3 Recovery Capacity

The ability to recover is embedded in all understandings of resilience and encompasses physical, mental and socio-economic aspects. The capacity to reinstate the built environment quickly after flooding minimises the distress and disruption caused by flood events (Samwiga et al., 2004, Active Learning Network for Accountability and Performance in Humanitarian Action (ALNAP), 2008). Rapid damage and loss assessment and effective damage repair arrangements can be highly effective in enhancing community resilience. Similarly, recovery plans, prepared in advance of flooding, increase the likelihood of a swift return to normality, and even lead to an improved and more resilient city (Jha, 2010).

Central to recovery planning is the provision of necessary resources and the ability to direct them effectively to the ones in need while working towards enhancing the future resilience of cities through implementation of resilient building techniques. Financial resources can be provided through many sources including donations, disaster risk financing and insurance products, such as catastrophe funds or public funds, as well as through existing community-driven development program, or social protection and livelihoods support programs, such as cash-for-work transfers. The balance between private financing and communal or charitable disaster pools requires an assessment of the local capacity, risk and designation regimes as well as broader socio-economic and cultural considerations. Nation-wide schemes should fit the needs of local populations and include multi-stakeholder perspectives.

The case of the 2011 floods in Queensland, Australia, illustrates a number of recovery challenges related to post disaster financing and insurance arrangements. In the three consecutive years beginning with 2009, serious flooding and cyclones affected large parts of the state of Queensland, located in the north-east of Australia. The estimated total cost of the recent floods and cyclones during these three years is US$ 10.46 billion (Bloomberg, 2012). However, one month after the severe floods of 2011, only 10 percent of the total of US$2.1 billion worth of private claims had been paid. In January 2011 the Government of Australia ordered a review into all aspects of the response and the aftermath of the 2010 and 2011 flood events (Queensland Flood Commission of Enquiry, 2011, Insurance Australia Group, 2011). The main insurance aspects to be reviewed were: the performance of private insurers in meeting claims for floods and other natural disasters; the potential effect of national government intervention in disaster insurance such as subsidised insurance premiums for individuals and small businesses in high-risk areas; and the need for a national disaster fund to support other financing pools. The Commission collected evidence from individuals and communities that experienced difficulties and delays in recovery due to the denial of their insurance claims and consulted widely after the interim report was issued. The Queensland Floods Commission held a second round of hearings in September and October 2011, and the final 658 page report was published March 2012 (Queensland Flood Commission of Enquiry, 2012). The report proposes changes to the insurers code of conduct in relation to dealing with disputed claims but deferred more fundamental changes until the results of consultations on the wider enquiry into hazard finance by the National Disaster Insurance Review Panel (National Disaster Insurance Review Panel, 2011). The report recognised the importance of the private insurance mechanism to empower communities to help themselves and promoted the provision of improved hazard information and advice on
protection and mitigation for improved resilience (Insurance Council of Australia, 2012). This information is now beginning to be more widely available.

3.4 Adaptive Capacity

The ability of cities to adapt to changes, coping with present hazards without compromising future options is increasingly important in the light of uncertain futures. The drive to enhance adaptive capacity tends to promote flood risk management measures which are incremental in application, reversible and present so called low-regret solutions that bring benefits under a range of future scenarios (Hallegatte, 2009). Adaptive capacity includes dimensions which are generic in nature, focusing on improvements in education, income-levels and health. There are also dimensions specific to a particular hazard such as flooding (IPCC, 2007) or which address a subset of adaptive challenges.

Actions to address environmental issues in the city of Bamako, the capital of Mali, contained examples of both generic and specific adaptive strategies. In 1999, flash floods cased death and destruction throughout Bamako. At the same time, socio-environmental problems plagued the population, including non-existent wastewater collection and treatment, inadequate solid waste management, unhygienic individual behaviour, and poor urban management. Problems were particularly severe in the informal peri-urban settlements inhabited by 45 percent of the inhabitants (Setchell, 2008). A four year programme to improve stormwater management was undertaken in one of the most flood-affected areas of the city including: restoration of channel capacity through the removal of several hundred tons of accumulated refuse and debris, which improved drainage capacity and reduced flood risk; improving water retention capacity by constructing slip trenches (soak pits), reducing runoff volume and impacts; and establishing a refuse collection and disposal service. For the first time in the city, the programme planning involved stakeholder participation in combination with a comprehensive planning framework. The capacity of non-governmental organizations (NGOs), community-based organizations (CBOs) and informal sector groups involved in the process was strengthened so that they would be able to: prepare terms of reference; undertake further studies; and conduct public information campaigns (UN habitat, 2010a, UN Habitat). Implementation of this programme also involved setting up of partnerships between local profit-seeking bodies called Groupement d’Intérêt Economique (GIEs) and the communes of Bamako, which have institutional responsibility for waste collection. Furthermore, links were made with individual households and local farmers who use up to 60% of the collected waste. Local employment opportunities were created related to drainage and retention improvements, refuse collection and disposal, and the initiation of a composting operation (UN habitat, 2010a).

This case study illustrates that tackling flooding and environmental threats while supporting local institutions and stakeholders and promoting good governance, can significantly contribute to an improvement of a city’s adaptive capacity, making communities resilient to future challenges in flooding, while addressing urban management needs (UN Habitat).
4. Implementing the principles

Through an iterative comparative approach in preparation of ‘Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century’ and during the numerous local and international workshops led to the distillation of twelve key principles for policy and practice in integrated urban flood risk management. These are listed below in table 1.

**Table 1: Twelve key principles for integrated urban flood risk management (source (Jha et al., 2012))**

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<td>1.</td>
<td>There is no flood management blueprint.</td>
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<tr>
<td>2.</td>
<td>Designs for flood management must be able to cope with a changing and uncertain future.</td>
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<tr>
<td>3.</td>
<td>Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.</td>
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<td>4.</td>
<td>An integrated strategy requires the use of both structural and non-structural measures and good metrics for “getting the balance right”.</td>
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<td>5.</td>
<td>Heavily engineered structural measures can transfer risk upstream and downstream.</td>
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<td>6.</td>
<td>It is impossible to entirely eliminate the risk from flooding.</td>
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<tr>
<td>7.</td>
<td>Many flood management measures have co-benefits over and above their flood management role.</td>
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<tr>
<td>8.</td>
<td>It is important to consider the wider social and ecological consequences of flood management spending.</td>
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<tr>
<td>9.</td>
<td>Clarity of responsibility for constructing and running flood risk programs is critical.</td>
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<td>10.</td>
<td>Implementing flood risk management measures requires multi-stakeholder cooperation.</td>
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<tr>
<td>11.</td>
<td>Continuous communication to raise awareness and reinforce preparedness is necessary.</td>
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<tr>
<td>12.</td>
<td>Plan to recover quickly after flooding and use the recovery to build capacity.</td>
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Integrated urban flood risk management is an iterative five step process starting with understanding the hazard, through to identifying measures, planning, implementing and evaluating the results. It is recognized that measures will reduce but never eliminate risk. Similarly, the maximum potential reduction may not be provided in the short-term due to practical and resource considerations. Risk reduction should be a long-term target to be approached through a series of cycles. The principles must be borne in mind at each step in the process and in each iteration. By combining the principles with the planning framework it is possible to derive a checklist for benchmarking the flood risk management process as shown in table 2.

**Table 2: Benchmarking the flood planning cycle (after (Jha et al., 2012))**

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<table>
<thead>
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<tbody>
<tr>
<td>1. Understand</td>
<td>Multiple sources of hazard and risk and extreme events.</td>
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<tr>
<td></td>
<td>Potential future changes due to climate change and urbanisation.</td>
</tr>
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<td></td>
<td>Diversity of flood management roles and urban form.</td>
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<td>Capability and limitations of approaches.</td>
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<td></td>
<td>The wider catchment.</td>
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<td></td>
<td>Wider urban management and hazard context.</td>
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<td></td>
<td>Vulnerability and resilience in its broadest sense.</td>
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<td></td>
<td>Governance structures surrounding communities at risk.</td>
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<td></td>
<td>The local assessment of need using participatory approaches.</td>
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<tr>
<td></td>
<td>How to share information in the most accessible way.</td>
</tr>
</tbody>
</table>
2. **Identify**

- Approaches to tackle each source of flood hazard.
- Approaches which are robust to future changes.
- Synergies with existing roles.
- Structural and non structural measures for full consideration.
- Whether risk is transferred and to where.
- What will happen if measures are overtopped or fail?
- Synergies with other urban management goals.
- Environmental and social impacts of proposed measures.
- Capabilities of local networks, experts, businesses, NGOs and other stakeholders.
- Costs, benefits and consequences.
- Ways of dealing with residual risk such as financing for speedy recovery.

3. **Plan**

- Re-examine existing structures, measures and plans.
- Identify under what circumstances plans would need reviewing.
- Consult widely and engage in cross departmental planning.
- Plan for the long term including maintenance, forecasting and warning systems.
- Plan to set up compensation schemes, consult widely.
- Plan to fail gracefully when design levels are exceeded.
- Consult widely and engage in joint planning with other stakeholders.
- Use metrics such as Multi-criteria analysis to make the process inclusive.
- Engage all stakeholders but clearly define their remits.
- Put in place agreements for support and mutual cooperation.
- Share and consult on detailed plans.
- Plan emergency procedures, put disaster management infrastructure in safe zones.

4. **Implement**

- Tailor implementation to local customs and preference.
- Build in flexibility.
- Coordinate the implementation to fit in with other urban cycles.
- Prioritise the most cost effective measures, often nonstructural.
- Communicate changes in risk.
- Set up warning and evacuation systems to offset residual risk.
- Consider co-financing opportunities and involve all stakeholders.
- Involve stakeholders in evaluation and put in place grievance procedures.
- Assign responsibilities using legislation or redefinition of departmental roles if necessary.
- Involve the maximum number of stakeholders in the implementation.
- Conduct awareness campaigns around new roles and the limits of implemented measures.
- Prioritise critical infrastructure and the vulnerable and build back better.

5. **Evaluate**

- Recognise relative risk reduction.
- Test robustness to future scenarios.
- Monitor agreed targets.
- Identify routes to failure.
- Monitor awareness of changing risk.
- Measure and report performance against planned protection levels.
- Identify flood benefits and wider benefits separately if possible.
- Use participatory approaches to evaluate social and environmental impacts.
- Get feedback from stakeholders who were involved in the planning stages.
- Ensure stakeholders goals are addressed in the evaluation.
- Communicate the results of evaluations including the successful avoidance of damage.
- Check whether recovery after events has increased the resilience to future events.

Source: After ([Jha et al., 2012](#)).
Each step relies on community and stakeholder consultations, and where possible, should adopt local solutions which fit communities’ needs. These steps bring the concepts of resilience, consultation and the importance of local needs and capacity assessment to the attention of flood risk management planners. The use of an iterative cycle maximises adaptability to changing circumstances.

5. Summary and Conclusions

Flooding is a serious threat to the safety and economic wellbeing of populations of many cities worldwide. The threat from flooding is growing with increased urbanisation, rapid growth and densification of metropolitan areas in and around our major cities and changing climates also contribute to a future that may see more flooding from multiple sources with greater unpredictability. Action to tackle flood risk is urgently needed and many established measures can effectively reduce risk but action is often delayed or rejected. While it is not possible to completely eliminate flood risk, there is a need to develop approaches that are resilient to continued flood hazard and integrated into wider development plans.

Promoting an integrated flood risk management approach can be challenging as it involves approaches that may run counter to the natural desire to build and rely on structural (engineered) defences. While traditional methods have served reasonably well in the past, saving millions of lives, but they may not be flexible enough to adapt to an uncertain future of climate change and urbanisation trends. Modern flood risk management thinking emphasises the resilience of the built environment through a balanced approach of structural and non-structural measures, based on a wide participation of stakeholders and communities. Non-structural measures are inherently more flexible, and can prove extremely cost-effective. A balanced approach can support the adoption of robust measures with benefits under a wide range of future scenarios.

The application of the five step integrated planning and implementation cycle in the context of the twelve key principles outlined in Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century can assist policy makers to design integrated flood risk management programmes for cities that will lead to a more resilient future. They provide a framework for decision making that can lead to systematic implementation of alternative options while encourage participative approaches that will improve the stakeholder buy-in and enhance the sustainability of specific local solutions.

However, the existence of a guiding framework is just one step in building more resilient cities for the 21st century. The impetus to resource and engender change requires that the forward-looking flood risk management and adaptive resilience thinking remains high on the political and policy agenda. The role of risk management, urban development and city planners is critical in facing the flood risks.

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Critical Factors for Successful Housing Reconstruction Projects Following a Major Disaster

Zabihullah Sadiqi “Wardak”¹, Vaughan Coffey², Bambang Trigunarsyah³

Abstract

Post–disaster reconstruction projects are often considered ineffectual or unproductive because on many occasions in the past they have performed extremely poorly during post-contract occupation, or have failed altogether to deliver acceptable outcomes. In some cases, these projects have already failed even before their completion, leading many sponsor aid organisations to hold these projects up as examples of how not to deliver housing reconstruction. Research into some previous unsuccessful projects has revealed that often the lack of adequate knowledge regarding the context and complexity involved in the implementation of these projects is generally responsible for their failure. Post-disaster reconstruction projects are certainly very complex in nature, often very context-specific and they can vary widely in magnitude. Despite such complexity, reconstruction projects can still have a high likelihood of success if adequate consideration is given to the importance of factors which are known to positively influence reconstruction efforts. Good outcomes can be achieved when planners and practitioners ensure best practices are embedded in the design of reconstruction projects at the time reconstruction projects they are first instigated. This paper outlines and discusses factors that significantly contribute to the successful delivery of post-disaster housing reconstruction projects.

Keywords: Post-disaster housing reconstruction, success factors, project outcomes

1. Introduction

The reconstruction of domestic dwellings in large quantities after a significant disaster presents many challenges and is a daunting task (Blanco et al. 2009). Reconstruction projects are constantly threatened by such challenges right from their initiation through to their closure. Even though post-disaster reconstruction management and planning as a whole still remain quite under-researched, sporadic attempts have been made by both professional bodies and academic researchers to determine the most common factors contributing to the poor performance and reasons for failure of some of the least successful projects. For examples, Pyles (2007) in her study of “Community Organizing for Social Development” argues that poor consideration of community organising is a challenge for

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social development of affected communities after a disaster. Williams (2006) undertook a study of community participation in post-apartheid South Africa and revealed that the lack of existence of any community organisations was the main impediment to effective community participation in reconstruction. Hayles (2010) explored some of the main challenges for non-government organisations (NGOs) involved in post-disaster reconstruction. In another instance, Fayazi (2011) compared the outcome of two different methods used in the reconstruction of permanent houses after the Manjil earthquake in 1990. The author (ibid. 2011) identified that the absence of an appropriate reconstruction program, neglect of the main principles of traditional architecture and failure to consider environmental effects on buildings were some of the main problems encountered during the rebuilding of permanent houses. This paper, which forms part of a larger ongoing PhD research project, examines briefly the nature of post-disaster housing reconstruction projects and underlines some of the important factors that determine the outcomes of such projects. A comprehensive review of the extant literature was conducted to explore desirable practices in reconstruction projects that have already been successfully implemented. Case studies of past projects from around the world are examined and factors which positively support and influence post-disaster reconstruction outcomes are identified. QSR International’s NVivo 9 qualitative data analysis software was used to organise and analyse the information.

2. Post-disaster housing reconstruction projects – success factors

2.1 Community participation

Although those people and communities directly affected by a disaster are the first to engage with the emergency, they are often perceived as being mere victims rather than the potential critical driving force behind reconstruction (Jha et al. 2010; Pius Mulwanda 1992). Local communities and the survivors of disasters play a crucial role in post-disaster reconstruction and their participation ultimately determines project success (Lawther 2009; Lyons 2009; IFRC and ICRC1994; Lemanski 2008). Post-disaster reconstruction is a complex and highly demanding process that involves a number of different and well coordinated courses of action. Therefore, it is vital that these complex activities are well planned (Roseberry 2008) and subject to thorough consultation, and effective collaboration with a wide range of community members (John 2008; Pius Mulwanda 1992). Since community members have the most knowledge about their own communities and specific building requirements, often possessing a good technical knowledge of appropriate building techniques, it is critical to involve them when conducting community needs assessments and planning reconstruction projects (Lawther 2009). Communities must also be encouraged and supported to use their own reconstruction techniques when rebuilding their houses (Pomeroy et al. 2006; Jha et al. 2010; Gaillard and Texier 2010; Kaklauskas, Amaratunga and Haigh 2009; Geis 2000; Ganapati and Ganapati 2009).

Communities play a vital role in rescuing human lives during the immediate post-disaster emergency and humanitarian relief phases (Shaw 2006; Dikmen 2005) and in planning and developing the subsequent medium recovery and long-term reconstruction. One study of community participation in the aftermath of the 2004 Indian Ocean tsunami revealed the significant role that the Aceh-Indonesia community played in disseminating information about
the scale and effect of the disaster to relief agencies, when many government units did not function and could not provide this critical information. The information provided by local communities in Aceh-Indonesia expedited relief efforts and established the way forward for planning of post-disaster reconstruction (Steinberg 2007). Affected communities in Aceh-Indonesia also played a key role in establishing the identities of those individuals and families affected by the Tsunami, and their eligibility for assistance (Da Silva and Batchelor 2010). An analysis of the factors contributing to success, failures and processes of two housing reconstruction policies adopted in the aftermath of the 2004 Indian Ocean Tsunami concluded that owner-driven programmes in Sri Lanka had higher success rates than donor-assisted programmes. While the number of dwellings produced by owner-driven programmes reached 48,981 (73% of all houses) by December 2006 (two years after the tsunami), the number of houses produced through donor-assisted programmes remained at only 12,207 (19% of all houses) (Lyons 2009).

Thus, it is clear that community participation is important at all stages of post-disaster reconstruction, and since a community is composed of different groups of people, suitable methods to include these groups proactively in the process of reconstruction need to be devised (Lloyd-Jones 2006). Attention must be paid to ensure that disadvantaged members of the affected communities, such as vulnerable women, children, the elderly and persons with disabilities (El-Masri and Tipple 2002; Pyles 2007; Lankatilleke 2010; Leon et al. 2009; Lloyd-Jones 2006) are properly included in the reconstruction process, and that the design of post-disaster reconstruction projects responds to their fundamental requirements (Barakat 2003; Snider and Takeda 2008; Krishnadas 2007). Effective participation must begin with, and be promoted by, effective community empowerment (El-Masri and Tipple 2002).

2.2 Community empowerment

Empowering communities to participate in reconstruction can provide an opportunity for community members to contribute their knowledge and skills to the process that will in turn most deeply affect their future lives. Empowerment is made possible when affected communities are effectively involved in all stages of the post-disaster reconstruction (Jha et al. 2010). Davidson (2010) highlights the existing complex relationships between the multiple stakeholders and the significance of this in post-disaster reconstruction and argues that the selection of procurement strategies must best suit the requirements of the reconstruction programme. In the context of post-disaster reconstruction and disaster management, empowering local communities should not be perceived as merely a technical capacity-building exercise. Rather, it should be seriously accepted as a holistic approach towards utilising local knowledge and involving affected communities and local institutions in the process of reconstruction (Allen 2006).

Community empowerment in a post-disaster project must include improving community access to information and services, and thus enabling community participation in decision-making (Maier 2001; Bosher and Dainty 2011; Maginn 2007) and increasing control over the procurement and consumption of local and natural resources (Pomeroy et al. 2006; Alireza 2008). Building local capacity is vital for effective participation during reconstruction as well as for producing a more sustainable built environment (Pyles 2007; Allen 2006; Pomeroy et
al. 2006; Hayles 2010). After the 2006 Jogjakarta earthquake in Indonesia, a cash grant for construction materials and a skills exchange reconstruction project facilitated the building of 12,250 shelters in 10 months; and in Kenya after the 2008 election violence, the affected community was successful in building 255 transitional shelters. The Kenyan pilot shelter project was successful mainly because the community received technical training and also construction materials prior to project implementation (Leon et al. 2009). Case studies relating to the transitional settlement and shelter processes in Afghanistan, Democratic Republic of Congo, Eritrea, Honduras, India, Indonesia, Kenya, Liberia, Mozambique, Pakistan, Peru, Russia, Rwanda, Somalia, Sri Lanka and Sudan, which were compiled and analysed by these authors (ibid. 2009), revealed that empowerment enabled affected communities to participate more productively in a transitional settlement and building of sustainable houses. The work and involvement of Denise Thornton, a resident of New Orleans, provides a prominent example of community participation in reconstruction. In the aftermath of Hurricane Katrina in 2005, Thornton’s dedication and motivation to rebuild her destroyed house inspired the entire community to return to their devastated homes and demonstrated to them that rebuilding was indeed possible (Maret and Amdal 2010). As part of the integrated approach to successful post-disaster reconstruction management, community participation and empowerment require a strong line of communication and information dissemination (Lawther 2009).

2.3 Communication and information dissemination

In post-disaster situations, it is imperative to establish a strong and reliable line of communication and an information dissemination system. People’s awareness of the existing opportunities for participation and their relevant importance for immediate recovery and long term housing reconstruction is crucial (Lawther 2009; Galtung and Tisné 2009). In May 2000, Roombeek, a city of Enschede in the Netherlands, was destroyed by the explosion of fireworks stock being stored in a warehouse (Denters and Klok 2010). A case study of the post-disaster reconstruction conducted by these authors (ibid. 2010) revealed that in the aftermath of the explosion, the established information rules had been successful in stimulating wider public participation in rebuilding Roombeek. These rules ensured that the rebuilding process was transparent and that residents were well informed of the participatory process and the available opportunities for participation. Chang et al. (2011), based on their investigation of reconstruction resourcing after the 2008 Wenchuan earthquake in China, concluded that post-disaster environments are complex and dynamic, necessitating a great degree of resources coordination and communication among stakeholders. These authors suggest that well established and successful resource coordination requires systematic data collection, information systems, and communication and coordination mechanisms. In relation to the significance of communication and information dissemination in post-disaster reconstruction, El-Masri and Tipple (2002) argue that local authorities should promote dissemination of knowledge about the cultural and social condition of the affected communities amongst stakeholders.
2.4 Community culture and beliefs

An understanding of the community involved in reconstruction is of the utmost importance in establishing a constraint for delivering successful projects and managing community participation (Allen 2006). Housing design must meet both the socio-economic and cultural requirements of the affected communities and should also allow for future expansion of such accommodation based on people’s changing needs (Diacon 1997; El-Masri and Tipple 2002). The role of religious groups can be vital in mobilising and persuading affected communities to return to the affected area and actively participate in rebuilding their houses (Denhart 2009). As a direct result of Hurricane Katrina, 1,300 people died and 1,000,000 were evacuated (Colten, Kates and Laska 2008). In order to rebuild New Orleans, the affected communities had to make the difficult decision to return to the devastated area, which largely depended on whether their displaced neighbours also returned. In this uncertain and difficult time, members of the Mary Queen of Vietnam (MQVN) Catholic Church in New Orleans East played a key role in organising and mobilising a wider displaced population through working with its lay leadership, facilitating a great level of social coordination and providing emergency assistance to returnees (Chamlee-Wright and Storr 2009). Alexander (2004) suggests that giving consideration to the affected communities’ emotional and economic attachment to their home areas increases the chances of success as compared to adopting a more radical solution that has a propensity to remove past attachments. El-Masri and Kellett (2001) in their study of post-war reconstruction in the village of al Burjain in Lebanon, highlighted that even though the displaced members of the affected community had total control over the reconstruction of their new houses in the host village, most of them expressed strong positive attachment towards their original villages and dwellings and had a strong desire to return. The authors (ibid 2001) concluded that it is imperative to consider both the socio-economic and cultural aspects when planning reconstruction.

2.5 Support from local government

Following large scale disasters, the rebuilding of houses requires a more contributive community capacity that may not be immediately available locally. So, the affected members may not be able to reconstruct their houses without substantial external support (Alam 2010). Local government plays a vital role in establishing budget priorities and is able to establish effective lines of information dissemination that can help other stakeholders make more informed and logical decisions (Olshansky et al. 2008). Therefore, incorporating the initiatives from local governments in disaster management is another important contributor to effective post-disaster response (Ye and Okada 2002). As mentioned previously, communities often possess great intellectual and physical resources; however, these resources may be obliterated by the existing event. While a community may still be able to transform itself without external aid, effective interaction with governments and non-governmental organisations through a well defined framework can substantially expedite the reconstruction process (Gauthamadas, Negi and Shyamprasad 2005). In the aftermath of the May 2000 fireworks store explosion, the role of the Roombeek-Netherlands local government in providing opportunities for participation in rebuilding the city was critical (Denters and Klok 2010). During the Indian Ocean Tsunami in 2004, the water that severely
devastated Tamil Nadu (India) penetrated almost 1.5 kms inland. An estimated 984,564 people were affected and 126,182 houses damaged or completely wiped out. In an effort to bring life back to normality, a massive reconstruction effort had to be undertaken. To effectively coordinate and strengthen the recovery mechanism, the state government selected personnel from different departments across the state. These personnel were placed at different managerial levels and were delegated considerable decision making and financial authorities. This level of administrative authority and the lack of political and bureaucratic influence over the recovery process led to a more effective response compared to other states and even countries (Srinivasan and Nagaraj 2006). Whilst it is true that local community participation is possible even without the commitment from local governments or non governmental agencies, often more successful participation is assured by such commitment from, and effective cooperation of, the external agencies (Lawther 2009). The role of local government is crucial in enhancing the resultant human settlements and developing resilient communities. Local authorities are responsible for the implementation of development projects and application of central government policies (El-Masri and Tipple 2002). Pyles (2007) advocates that community based reconstruction efforts must involve participation from the most vulnerable members in order to further strengthen the capacity of local community and government.

3. Conclusion

The extant literature suggests that an absolute knowledge of the complexity of reconstruction, a detailed understanding of the factors contributing to failure, as well as those supporting reconstruction, are crucial for rebuilding domestic dwellings successfully after a major disaster. This paper touches upon five common factors that are believed to impact positively on the outcomes of post-disaster housing reconstruction projects. The findings reveal that reconstruction projects can be delivered satisfactorily when among others, factors such as community participation and community empowerment, effective communication among the stakeholders (in particular with members of the affected communities), community cultures and beliefs and support from the local government, are considered. Community participation that ensures the inclusion of beneficiaries from all sectors of the affected community and at all stages of post-disaster reconstruction is important and should be enhanced by effective community empowerment. Successful post-disaster reconstruction projects require a strong and reliable line of communication and an information dissemination system, which can be established with the support of the local government. Housing designs that are considerate of the socio-cultural and economic requirements of the affected communities are more acceptable and therefore stand a better chance of success. The uniqueness of post-disaster reconstruction projects and their contextual requirements mean that the sponsors and practitioners involved in these projects must adapt their practices to respond to the complexity inherent in these projects and so achieve more desirable outcomes.
References


Determinants of Urban Resilience: an exploration of functional response diversity in a formalising settlement in the City of Tshwane, South Africa

Albert Thomas Ferreira¹, Prof. Chrisna Du Plessis²

Abstract

Urban centres in the developing world are experiencing massive settlement growth often in the form of informal settlements with their concomitant informal economies. South Africa is facing similar trends, and the City of Tshwane is no exception. Apart from facing poor living standards and increasing inequalities in service delivery, these urban centres are also vulnerable to global and local economic instability. Improving the resilience of these settlements is one of the main challenges in the process of their upgrading and formalisation according to national and international development goals. This paper explores one of the determinants of urban resilience which is the response diversity in a formalising settlement in the City of Tshwane with specific reference to the function of retail activity provided in these areas. The diversity of responses to this function ranges from, (depending on the scale of operation) an informal trader to a large shopping centre. This paper further examines how the formalising settlement in terms of economic activity responds to the function of retail. This includes the role of the informal sector in the process of adapting to the formalising process. The informal economy is an important role player in South African cities and other developing countries. However, it is often disparaged as a defect in the system which poses a threat to the formal economy and which must therefore be suppressed, if not eradicated. This paper argues that the informal economy plays a vital role in the resilience of human settlements, especially in the face of poverty, unemployment and inequitable access to social services. This will be done by examining various case studies of shopping centre establishments in formalising settlements and field observations. The paper concludes with a model that places the different responses to the function of commerce on a panarchy within the context of a formalising settlement based on certain characteristics. This model can be used as a tool to look at the interdependencies of entire functional groupings within the context of urban resilience.

Keywords: formalising settlements, urban resilience, response diversity, panarchy

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1 Introduction

The informal economy is an important role player in South African cities and other developing countries. However, it is often disparaged as a defect in the system which poses a threat to the formal economy and which must therefore be suppressed, if not eradicated. This paper argues that the informal economy plays a vital role in the resilience of human settlements, especially in the face of poverty, unemployment and inequitable access to social services. This argument is based on the notion of response diversity to particular functions in an ecosystem as a main determinant of resilience (Elmqvist et al., 2003; Walker and Salt, 2006) and the assumption that this concept can be transferred to social-ecological systems such as cities (Pickett et al., 2004; Talen, 2006; Du Plessis, 2012). As such it also draws heavily on the broader theoretical basis of resilience thinking (Gunderson and Holling, 2002; Walker and Salt, 2006, Resilience Alliance, 2010), including the concept of panarchy. The concept of diversity within resilience thinking suggests that an increase in response diversity would provide multiple redundancies to a specific function, which would mean the provision to that function is more stable, resulting in an overall decrease in vulnerability to specific threats to that function. With the introduction of a panarchy model of the various responses, potential interactions across scale can be discovered in the urban or social-ecological system context.

Through both a desk top study of previous case study work and direct observations in the field, this paper develops a panarchy model to explore the response diversity (in one functional category i.e. the response to the function of commerce/retail) in one township area in the City of Tshwane. This township has both formal and informal elements (from housing to transport and retail activities) within close proximity. For the purposes of this paper specific attention will be paid to the formalising of the retail and commercial activities in the area although other formalisation processes are also occurring. The case study will be based around the Central City shopping centre in Soshanguve/Mabopane with specific reference to the retail function of the area.

2 Contextual background

2.1 Townships: Formation and Persistence

Townships in a South African context refer to areas that were created by the Apartheid government (through institutionalised regulation) to mainly segregate the black African population to peri-urban locations away from the central white town or city. The remainder of the black population was located to ethnic “homelands” in far, resource inefficient locations (Zondi, 2011, p.11). The townships served as a low-cost labour pool for the adjacent white areas where most of the economic activities were created. The labour and education regulations and legislation were positioned to exclude the majority black population from economic emancipation and keep the township areas from developing independently from the white areas. Thus a “permanent” state of economic inequality was created. Most South African cities and
towns had this economic system in place (Zondi, 2011, p.11). Although township areas were formally planned, they could not support the large number of residents in terms of housing and economic activity. This resulted in the organic, spontaneous and unsanctioned formation of informal settlements in the township areas, as well as other locations closer to economic activity.

In Post-Apartheid South Africa, townships and the informal settlements within them have remained persistent. The township areas are in constant flux between formal and informal, permanent and temporary and serviced and non-serviced (Weakley, 2012). From an economic and planning perspective, government policy with goals of promoting sustainable, equitable and inclusive cities, has not been able to fundamentally change the apartheid spatial structure (although provision of services have increased dramatically). The continued influx of people (rural-urban, intra-urban, refugee) to these areas has happened much faster than housing and infrastructure could be provided. Informal settlements are essentially an adaptation strategy for people with a low asset base to access urban amenities which they cannot access in a formal way. Trade-offs are made by residents in informal settlements between relatively poor living conditions and some access to urban amenities and employment prospects.

2.2 The study area

Soshanguve/Mabopane is located 35 km north of the administrative capital of South Africa, Pretoria (both within the City of Tshwane Metropolitan Municipality, the third largest city in terms of area in the world). The name Soshanguve comes from the languages spoken in the area, i.e. Sotho, Shangaan, Nguni, and Venda, while the adjacent Mabopane was once in a former “homeland”. Soshanguve and Mabopane are peri-urban township areas that were established in the 1960’s and 1970’s respectively to relocate black Africans (into specific ethnic groups) from the nearby city of Pretoria or other areas in the region by the erstwhile Apartheid Regime. Challenges faced by residents are closely linked to their vulnerabilities such as crime, environmental hazards including fire and flood, and general conditions associated by poverty.

![Figure 1: Spatial structure of the study area, in Soshanguve/Mabopane based on field observations done by the author (Base map courtesy of Google Earth, 2012)](image-url)
For the purposes of this study a dynamic economic hub was chosen which is located around the Mabopane train station and the informal secondary transportation infrastructure provided by private minibus taxis in two taxi ranks flanking the station (described in Figure 1). The area has both informal and formalised settlements with varying levels of service provision. This area includes the Central City shopping centre, as well as two other formal shopping centres. The overall spatial character of the area is similar to a transport orientated development where the main structuring element is the transport infrastructure which supports the informal as well as the formal retail development (including the surrounding residences) surrounding the station (see Figure 1). The informal activity around the centre forms an “informal high-street” of mostly permanent buildings next to the movement paths (street) of pedestrians and cars, including the traffic island separating the opposing traffic streams. In other areas, informal flea markets are evident with less permanent structures including mobile street vendors. The area has a lot of movement in the form of both car and pedestrian traffic intertwining between the formally planned and the sprawling organic informal trade and transport.

3 Theoretical background: Urban Resilience and its Determinants

In order to understand urban resilience within the context of the Soshanguve/Mabopane township area, a brief overview of resilience and its determinants is required. Resilience thinking’ as a conceptual framework is constructed upon the idea of multiple metastable regimes separated by critical thresholds at multiple distinctive scales with cross-scale interactions (the panarchy) (Du Plessis, 2012). Within a panarchy, what happens on one scale influences and affects what happens at a different scale (both in time and space) (Simmie & Martin, 2010, p.34). Cross scale linkages or dynamic interactions exists within and between the sub-systems contained in a system, although they might not be at the same stage in the adaptive cycle, thus responses will differ depending on the scale of the nested systems (Resilience Alliance, 2010).

As one of the determinants of resilience in ecological systems, functional response is based on the concept of functional groupings that provide for a certain specific function such as the function of predators/consumption (Elmqvist et al., 2003, p.489). The responses to that specific ecological function range across scales from lions to spiders and bacteria. Response diversity is referred to “as the range of reactions to environmental change among species of the same function”, and it is seen as “critical to resilience, particularly during periods of ecosystem reorganisation” (Elmqvist et al., 2003, p. 488).

Similarly, as argued by Du Plessis (2012), in social-ecological systems, humans as dominant species also have functional categories/groupings which are determined by the users and resources of the urban environment. In a city different functional categories can be identified such as (but not limited to) business and commerce, residential, industrial, infrastructure, social facilities and green users. Du Plessis adds that within these functional groupings different responses and scales of responses can be identified i.e. in the functional grouping of commerce responses could range from an informal trader to a large shopping centre. Building the range of responses to each of the functional groups and on different scales, multiple redundancies are
built into the system which increases functional diversity within the city which in turn improves the resilience of the city (Du Plessis, 2012).

Multi scale interactions between responses have been studied from an ecological systems perspective. Elmqvist, et al., (2003) created a multi-scale model based on response diversity of herbivores found in a coral reef system (see Figure 2). Response diversity exists because various species operate at different spatial and temporal scales. Disturbances to ecological functions usually only affects some of the responses to the function meaning other scales are undisturbed and can persist.

![Figure 2: “The multiple-scale nature of response diversity in the functional group of herbivores of coral reefs. Response diversity is enhanced by species operating over a broad range of scales. Over fishing of large species resulted in a situation where grazing is maintained by a set of smaller species operating more intensively at faster intervals” (Elmqvist et al., 2003, p.492).]

4 Response diversity to the function of retail in a township area

From a regional economic resilience point of view, Simmie & Martin (2010) argues for an evolutionary approach to resilience rather than an equilibrist. The evolutionary approach to resilience focuses on how economies adapt to changing circumstances rather than returning to a previous state of being which the equilibrist perspective emphasises (p 31). Local areas that have more diversity in economic activities seem to be less vulnerable to perturbations or at least can recover faster from them. Resilient regional economies depends on both longer term and shorter term processes to function. Jacobs adds that a combination of mixtures of activities is fundamental to the creation of successful neighbourhoods (Jacobs, 1969). The importance of neighbourhood resilience has been echoed by various authors (Jacobs, 1969; Tallen, 2006) who suggests that increasing social diversity, income diversity and land use mix will lead to more stable and resilient neighbourhoods economically and socially. Within a township context
this could be crucial in providing more stable economies for a vulnerable and emergent population.

4.1 Commercial and retail investment “landscape” within townships

The retail sector in South African township areas has changed drastically in the past two decades. The retail environment pre-2000 was dominated by informal small scale businesses offering products for the low-income consumer market. Overall spending done in this period was out of the township areas in more established shopping destinations such as the core CBD of the adjacent town or city. This trend has been reversed drastically with the development of shopping centres in “almost all township areas with sizeable population numbers” (Ligthelm, 2008a). The reason for this dramatic shift is the emergence of the black middle class. The Bureau of Market Research at the University of South Africa has recorded the relative market expansion from 1994-2004 which indicates the growth in household expenditure of black households of 239% in that period, compared to white households of just 110% (Bureau of Market Research, 2008). The relative income of black households is very low compared to that of white household but the absolute number of potential base is much bigger (Statistics South Africa, 2012). The provision of the social grant system in South Africa for lower and no income persons have further provided a more stable income, thus decreasing their overall vulnerability and making it more viable to invest in lower income areas such as townships (Urban LandMark, 2011).

Within developing countries, the informal sector provides access to livelihoods, provision of goods and services to the marginalised, including food distribution, and can act as a gateway out of extreme poverty. With this in mind policies that govern economic development in urban centres in the developing world should be sensitive to the existence of the informal and rather than marginalising the sector, put it firmly into the development focus to facilitate the move from survivalist to entrepreneurial enterprises (Rogerson 1996, p179). A more holistic view of economic development is also needed in a formalising context in which the formal businesses sector can also start to explore potential synergies that exist between them and the informal sector (Urban LandMark 2011). Integration and support of informal activities can bridge the segregated nature of South African cities through the exploration and allocation of both private and public policy initiatives (Rogerson 1996). These initiatives can include private business strategies which can integrate the informal and formal, i.e. in the case of the study area the retail typology that exist can give way to new retail forms. The typical shopping centre retail typology focuses inward whereas the study area new forms can be introduced such as encouraging high street retail forms leading up to the shopping centre (Urban LandMark 2011).

4.2 Shopping centre development and related impacts within townships

Although the existence of shopping centre development in township areas is not completely new the pace of development has dramatically increased since 2000. Investors and developers in the formal retail centre development market have realised the potential in township areas.
Currently the biggest growing segment in retail development is the lower income brackets as market saturation has been achieved in many more established traditional retail investment locations, not to say that investment in township areas are not without risks (Urban LandMark, 2011).

Within the township context the development of formal retail activity is one of the only non-governmental investment activities into these areas. Notwithstanding the positive impacts of formal retail developments in formalising areas such as providing increased access to higher order goods and services (including access to banking services) to residents, some negative impacts have been recorded in the local economy. These include the increased competition in the informally dominated commercial/retail sector of the areas, increased openness to global market fluctuations and other lifestyle related impacts such as increased debt exposure (Urban LandMark, 2011).

A study conducted by Ligthelm (2008a), which measured the impacts of recent shopping centre development in Soshanguve/Mabopane, points to an overall decrease in township informal and small formal business within the first six months of the shopping centre opening. The study showed evidence of some of the customers of the original township business gravitating to the shopping centres, but the overall survival of the original businesses was due to adaptation strategies. The main adaptation strategies used by the spaza/tuck shops (small informal sector retail business operating from a residential home or zoned stand) centred on finding a niche that the large shopping centres could not fill, such as moving to a location convenient to consumer dwellings, personalized customer service, flexible business hours, satisfying emergency needs, access to credit facilities and availability of goods in small quantities (Ligthelm 2008a, p 52).

In further studies in Soweto (a large township in Johannesburg), Ligthelm (2008b) commented that small enterprises in townships that were most vulnerable to the new developments were those located in old shopping centres, businesses offering daily household necessities and those businesses closer to the newly developed shopping mall. Similar studies conducted in Soweto points to much more positive interactions between the newly developed shopping centres and the existing business. Studies commissioned by Urban Landmark on the impact of Jabulani Mall in Soweto and Central City in Soshanguve/Mabopane indicates a marked increase in shopping done in the area after the shopping centre development, as well as reduced travel time and transport cost to formalised shopping facilities. Initially support for local traders as an overall percentage of money spent on retail goods and services did decrease with the introduction of the shopping centre. However, the overall income from consumers increased, reducing the impact on traders.

From a consumer perspective the new development was acceptable to very positive, in most cases reporting a need for the mall to expand. Bearing in mind that the circumstances differ similar trends have been noted in other township areas (Urban LandMark, 2011, pp.37-39). Although negative impacts have been recorded, the over 800 street traders in the vicinity of the Mabopane train station is evidence that informal businesses can function and even thrive in the
same area of the formal centres such as Central City, by providing goods and services not provided in the centres or by simply offering a more convenient shopping experience (Ligthelm, 2008a, p.52).

5 Towards a panarchy model of response diversity in the urban context

5.1 Typology of responses to the function of retail activity

The responses to the function of retail activity (distribution of goods and services) in townships have changed as previously mentioned. This change is due to certain characteristics that have changed in the study area, including a social-economic shift to higher and more stable incomes, together with market saturation of traditional investment locations. This change laid the foundation for the entrance of shopping centres into the township retail landscape (Urban LandMark, 2011). The pre-1994 retail landscape was dominated by informal and small formal activities including mobile street traders, informal traders; spaza/tuck shops; informal home-based services like barbers and taverns; and local convenience stores. From the late 1990's the retail landscape expanded to include neighbourhood centres; community centres, minor regional centres and regional retail centres (Ligthelm, 2008a: p 52; Urban LandMark, 2011: p 9). While the larger responses in terms of scale or size such as shopping centres have played a role before 1994 as residents used these facilities outside of the area, they have now become part of the township landscape and a direct competitor to the existing businesses in these areas.

5.2 Application of the panarchy model of response diversity in an urban context

As previously indicated by the response diversity model used to illustrate the ecological function (Figure 2) this paper argues for the use of such a model in the urban social-ecological context. As indicated by Simmie & Martin (2010) and Elmqvist, et al. (2003), large and small responses affect one another and can influence the overall resilience of the functional grouping, as well the resilience of the area.

The introduction of new responses (shopping centres) happened due to the change of neighbourhood characteristics or system change which resulted in viable locations for formal retail development. Such a model is described in Figure 3. With the introduction of the shopping centre into the area a perturbation was felt in the overall system with losses in revenue and changed customer patterns in the other responses (especially informal business). An adaptation period followed where the other responses reacted to the new entrant through various adaptation strategies as discussed earlier. A new equilibrium was reached replacing the previous equilibrium state, thus falling within the realm of adaptive change rather than static recurrence. A symbiotic relationship started to arise from the retail environment between the different responses (formal and informal activity).
The panarchy model for response diversity describing the function of retail activities plots the typology of responses according to scale and the response time. Each of the identified responses operates at their scale or level although they influence each other. From the resilience point of view diversification within the responses to functions are crucial in building adaptive capacity in neighbourhoods. The panarchy model illustrates how diversity to a specific function is structured according to scale according to variables such as scale of operation, capital needed for response, good and services provided, survivalist vs. entrepreneurial enterprises, capital available to response actor, vulnerability, adaptability (responses to adversity and response time), and openness to global/local economic fluctuations. The panarchy model does not indicate that one response is superior to another. Rather it proposes that the different manifestations of retail activities (typologies) are part of the same functional grouping and can potentially be in symbiosis with each other. For example, informal traders targeting the convenience shopper or shoppers who can only buy small quantities at a time can purchase their goods from bulk retailers inside the formal shopping centres, while the shopping centre caters for a clientele who may be making some more considered or bulk purchases. A trader providing a service such as a barber may also purchase his supplies from the shopping centre.

Adaptation strategies are key to the survival of businesses on all scales but may differ across scales. For example, on the lower end in terms of scale a mobile street trader can change location or type of product that is being sold, whereas a fixed shopping centre may respond by changing or upgrading the centre or implementing new advertising strategies (Ligthelm 2008a). Although more capital is available at the higher scale of the panarchy, the activities are more rigidly bounded in time and space. Comparative size of operation is also a factor which influences adaptive capacity, as the amount of potential available to the system increases with scale.
As shown in Figure 3 the response or adaptation rate becomes higher at the smaller scale, allowing actors at these scales to respond faster to a perturbation in the system. On the other hand, systems at larger scales have more accumulated potential that allows them to ride through smaller perturbations. An example of such a perturbation could be the operational difficulties and service delivery protests in the nearby train station which forced Metro Rail (the operating authority) to temporarily suspend its operations (SABC, 2012). Informal traders around the station targeting commuters may see a radical decline in patronage, but can shift their operations to the taxi stands or bus station. Traders linked to the funerary activities of the nearby cemetery may not notice any impact on their business or may see new niches opening up. Central City is a destination point in itself and its particular range of responses are not that directly linked to the functioning of the railways. It may be able to ride out the perturbation as its size provides robustness. However, it may be more vulnerable to perturbations at higher scales such as the national economy.

The increased diversity of responses provides multiple redundancies to a neighbourhood in terms of the provision of retail activities. Although increased competition might be perceived as negatively impacting the smaller scale operator in the commercial and retail sector, understanding the system as a panarchy suggests that a mutually beneficial relationship can develop between the responses to a specific function at different scales. Both for the users and the producers (providing the function) more diversity means less vulnerability to a range of perturbations as actors at one scale can step in to provide the function if actors at another scale fail. Actors at different scales can also provide responses in niches that are not open to actors at other scales. The increase in diversity of retail activity furthermore increases the amount of livelihood opportunities. Thus, when taken in the context of a township the existence of the informal economy, by adding diversity, contributes in many ways to the economic resilience of the township.

6 Conclusion

The application of ecological theory or practice in a social-ecological context has been led by various authors (e.g. Elmqvist et al., 2003; Folke, 2006; Resilience Alliance, 2010). The application was only recently extended to larger human-dominated systems such as urban areas which increases the need to explore these contexts (Resilience Alliance, 2010; Walker & Salt, 2006). The panarchy model gives insight into the dynamics that exist between responses at different scales across a functional grouping.

By developing a panarchy model of retail activities in the Soshanguve/Mabopane township area in the City of Tshwane in South Africa, an argument was built for the importance of the informal economy in providing response diversity to the function of commerce in areas characterised by poverty, unemployment and inequitable access to social services. This diversity aids in building the adaptive capacity in the economic system of these areas. It can therefore be illustrated that applying an ecological resilience framework to the understanding of urban dynamics may reveal
avenues for building resilience that see unexpected benefit in scenarios more often perceived as threats to a functional urban system.

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Disaster resiliency measurement frameworks

State of the art

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Abstract

Since adoption of the Hyogo Framework for Action 2005-2015 “Building the resilience of nations and communities to disasters”, the concept of disaster resilience has gained a wider interest and has become more popular among academic researchers and practitioners. Although the literature on urban studies and also the practical planning documents recurrently refers to resilience concept as a managerial principle behind making resilient cities and regions, operationalizing this concept in urban and regional planning context raises critical challenges in terms of its determinants and assessment.

There exist a number of disaster resiliency frameworks and indicator sets in varying degrees of comprehensiveness, accuracy and validity which offer communities a set of indicators to measure and manage their resiliency in order to preserve their critical structures and functions in the face of disturbances and recover quickly to the desired pre-disaster conditions.

This paper presents a critical review of resiliency models in the international urban resilience literature. It starts by defining and individuating the resiliency concept from other similar related concepts in disaster literature. Then it defines a framework for evaluation of resiliency models for aligning it to urban studies discipline, using a number of criteria including comprehensiveness, structure of components and indicator building methods, scale and unit of analysis, dynamics, data requirements, validation and operationality, and actual and potential applications. The paper ends by speculating about the most promising opportunities to further improve the resiliency models in urban context by using a set of resilience attributes which already embedded in the discourse of urban theory to evaluate the resiliency of each city’s built environment and the way people have adapted to that built environment to recover following a disaster. The findings suggest that fostering these resilience attributes within different urban components, can potentially assist in the design and planning of resilient cities which have an enhanced capacity to absorb the shock and recover quickly.

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Introduction

More than a decade after starting attempts for quantifying community resilience, endeavors are still ongoing to refine and develop more applicable resilience models (Gilbert, 2010). There exist a number of centers which are investigating urban resiliency in different scales, mostly based in the US. They have developed a few disaster resilience models of varying degrees of comprehensiveness and sophistication, some of which have been and are being applied to real-life communities and places for purposes of research and/or policy analysis and/or education (Manyena, 2006, Renschler et al., 2010b).

This paper offers an overview of current disaster resiliency models. It starts by examining the general definitional issues of the concept and then presents eight resiliency models which will be evaluated later by criteria such as comprehensiveness, models structure and components, methods, scale and unit of analysis, dynamics, data requirements, validation and operationality, and actual and potential applications. The paper shows that most of the existing frameworks have not been fully operationalized and validated with real data yet, and ends with speculating about the most capable avenues to further develop effective and implementable planning and design strategies for increasing the resilience of cities to the potential future shocks.

Disaster resilience

The concept of resilience originated in the field of ecology, but it has been used within a wide diversity of disciplines from psychology, geography, social science to engineering and systems science (Klein et al., 2003, Manyena, 2006, Norris, 2008). Following the work of Timmerman (1998), many definitions of the concept of disaster resilience appeared in the hazard and disaster field in the last three decades. They are all roughly comprised of two common features for disaster resiliency: 1) the ability to resist and absorb disturbances, 2) the ability to reorganize and recover reasonably quickly (retain the same basic structure and ways of functioning) (Mayunga, 2009). Long-lasting concerns from the research community focus on disagreements as to the definition of resilience, whether resilience is an outcome or a process, what type of resilience is being addressed (economic systems, infrastructure systems, ecological systems, or community systems), and which policy realm (counterterrorism; climate change; emergency management; long-term disaster recovery; environmental restoration) it should target (Cutter et al., 2010).

The wide use of resilience is the recognition of its value but that some applications have stretched the concept beyond its original meaning to the point that the concept itself runs the risk of becoming meaningless and a source of theoretical confusion. There are a few linked terms and concepts such as resistance, vulnerability and sustainability, coping capacity and etc. in disaster studies which have to be defined carefully to avoid using them in incompatible ways. Norris et al. (2008) make a distinction between resilience and resistance. In their terminology resilient communities and people bounce back from disasters, while resistant communities and people do not suffer harm from hazards in the first place. Tierney
believes that community resilience acts to counter vulnerability. A high level of vulnerability
does not necessarily mean that a community is not resilient; however vulnerability is often
indicative of an inability to resist or respond to disaster (Tierney, 2009). In Cutter’s adopted
definition, vulnerability and resilience are not totally mutually exclusive, nor totally mutually
inclusive. Vulnerability is the pre-event, inherent characteristics or qualities of the systems
that create the potential for harm (Cutter et al., 2008b). Vulnerability is a function of the
exposure (who or what is at risk) and sensitivity of system (the degree to which people and
places can be harmed) (Adger, 2006, Cutter, 1996). In contrast, resilience is the ability of a
social system to respond and recover from disasters and comprises those inherent
conditions that allow the system to absorb impacts and cope with an event, as well as post-
event, adaptive processes that facilitate the ability of the social system to re-organize,
change, and learn in response to a threat (Tierney 2007).

The concept of sustainability is central in resilience studies since it is inseparably linked to
the condition of the environment and the treatment of its resources. Sustainability, within the
context of natural disasters is defined as the ability to “tolerate—and overcome—damage,
diminished productivity, and reduced quality of life from an extreme event without significant
outside assistance” (Mileti, 1999) Unsustainable practice may cause more severe
environmental hazards. Large-scale deforestation, for example, was a factor in increasing
the flooding hazard in the 1998 floods in China, and loss of coastal wetlands is a contributing
factor to the severity of impacts of tropical storms and hurricanes on coastal Louisiana
(Wisner et al., 2004).

There are also diverse views about the relationship between the concepts of adaptive
capacity and resilience which makes the actual linkage very unclear. As mentioned by Smit
and Wandel (2006), some authors equate adaptive capacity with resilience and social
resilience. Gunderson (2000) defines adaptive capacity as system robustness to changes in
resilience; Carpenter et al. (2001) use adaptive capacity as a component of resilience that
reflects the learning aspect of system behaviour in response to disturbance (Gallopín, 2006).

**Methodology: Resilience models comparison**

In order to bring together and evaluate the existing frameworks in disaster resiliency, and to
answer the questions of what indicators can be used to measure community resiliency, we
conducted a critical literature review including a wide range of disciplines comprising of
environment, geography, planning and disaster, hazard and risk management. The eight
most cited models and frameworks for measuring and assessing disaster resiliency were
selected.

For the evaluation of disaster resilience models, an idealized disaster resiliency model has
first been sketched out as a benchmark by which the existing models can be evaluated. Five
types of resilience components are distinguished form literature for urban resiliency (See
Figure1). The circles show the performance level of the urban system which in the event of a
disturbance falls to a lower level depending on the resistance of the system. Each
component of urban resiliency will have a particular level of resistance, transitioning period
and recovery time to rebound to previous level of structure and functioning or to an upper
level of system’s performance. The response to disturbance depends on different factors in each part of subsystems which are interrelated and this makes it more difficult to get quantified. It may vary from system to system and from one kind of disturbance to another. In the following sections, we will examine properties of the models based on eight criteria. Since the principal motivation for understanding the drivers and processes of disaster resilience is to develop management plans to improve resiliency, assessments need to evaluate not only the baseline conditions but also adverse impacts, and factors that inhibit effective response (Clark et al., 1998). The transition from conceptual models to resilience measurement and assessment is challenging due to the multifaceted nature of resilience (Cutter et al., 2010).

Figure 1: A model of disaster resilience models

The majority of assessment techniques are quantitative and use indicators or variables as proxies since it is often difficult to quantify resilience in absolute terms without any external reference with which to validate the calculations (Schneiderbauer and Ehrlich, 2006). As a result, indicators are typically used to assess relative levels of resilience, either to compare between places, or to analyse resilience trends over time (Birkmann, 2006). The selected eight models will be evaluated according to the following criteria: comprehensiveness, structure and indicator building methods, scale and unit of analysis, dynamic, data requirements, validation and operationality, and actual and potential applications.

Comprehensiveness

The comprehensiveness of disaster resilience models can be assessed based on different dimensions of resiliency included in the models such as built environment, economic, social, organizational and different temporal phases of disaster (mitigation, preparedness, response, recovery) for different types of disasters (such as geological, climatic,…). Yet it doesn’t mean that the comprehensive model is necessarily better and more useful for policy making and planning purposes as it may result in too much complexity and serving too many purposes at one time.

PEOPLES stands for seven dimensions of disaster resiliency in this model: Population and Demographics, Environmental, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social-Cultural Capital.
As the third column of the Table 1 shows, DROP, CDRF and CDRI consist five dimensions of aforementioned asset pentagon but DROP and CDRF disregarded the ecological resilience purposefully due to complexity or data inconsistency and relevancy (Mayunga, 2009).

DROP, PEOPLES, ResilUS, CDRF and Systems diagram are comprehensive in the sense that they address at least four dimensions of resiliency. They all encompass the technical, social, economic, organizational dimensions. NIRA focuses on the technical dimension of urban networked infrastructure. All of the models except for systems diagram and URF are multi hazard models whereas systems diagram is a seismic specific model and URF basically has been developed for climate change resiliency and thus not consider the risk as an abrupt change to urban systems but a slow onset challenge. All of the models have considered the pre and post disaster conditions but only CDRF has specifically emphasized preparedness and response phases, which are neglected by others (Mayunga, 2009).

**Structure and indicator building methods**

A proper resiliency index should identify the distinct dimensions and related key indicators and also aggregates the dimensions in ways that reflect community realities. PEOPLES seems to be the most successful model in this aspect. It uses a geospatial-temporal distribution within its influence boundaries to define components of functionality. And then uses the interdependencies between and among these components to determine the resilience indicators of communities (Renschler et al., 2010a, Gilbert, 2010). For example, the physical infrastructure dimension in PEOPLES includes both facilities and lifelines. In the facilities category, they include housing, commercial facilities, and cultural facilities. But for lifelines, they include food supply, health care, utilities, transportation, and communication networks (Renschler et al., 2010c). In this particular dimension, historical and continuously gathered information through remote sensing and also Geographic Information Systems (GIS) plays a major role in assessing the resilience of all integrated urban systems and feed a predictive resilience model (Renschler, 2010). The third and fifth column of table1 has summarized the main properties of models and comparison for the most important aspects of these criteria.

In DROP, two main qualities have been considered for resilience of communities: inherent (functions well during non-crisis periods); and adaptive (flexibility in response during and after disasters). Cutter’s social vulnerability index, SoVI, in DROP has been used by PEOPLES to measure the social dimension of the resiliency. It integrates exposure to hazards with the social conditions that make people vulnerable to them to show the socioeconomic status of the community (Cutter et al., 2003, Cutter, 1996). They have also considered “Community competence” metrics in their index which represent how well the community functions pre-and post-disaster including a sense of community and ideals as well as attachment to place and the desire to preserve pre-disaster cultural norms and icons (Gilbert, 2010).

Metrics for measuring economic resilience have classically employed loss estimation models to measure the property loss and the effects of business disruption after disasters (Rose, 2004, Chang, 2010). PEOPLES, on the other hand, assesses both current economic activity and dynamic growth economic development (Renschler et al., 2010c).
ResilUS uses probabilistic methods within its loss and recovery modules. Each model state in ResilUS, is calculated through a comparison between a uniform random number and aggregation of all input variables which are stated as probabilities (e.g., the probability of restored water service in a neighbourhood) (Miles and Chang, 2011).

The key indicators in the Systems diagram are developed under the three complementary themes of resilience: “reduced failure probabilities”, “reduced consequences from failures,” and “reduced time to recovery” which in conjunction with four aspects of resiliency: robustness, redundancy, resourcefulness; and rapidity have been organized in three horizontal layers. These layers are representatives of situations where in the bottom layer no intervention is made, in the middle first level of action and decisions and in the top layer multi attribute information is collected and used for decision making (Bruneau et al., 2003). On the other hand, the key elements of the urban resilience framework (URF) are urban systems and social agents(Tyler et al., 2010a)

Organizational dimension indicators include the number of available response units and their capacity. It means in addition to personnel and equipment, organizational resilience also includes elements that measure how organizations manage or respond to disasters such as organizational structure, capacity, leadership, training, and experience (Tierney 2007).

**Scale and unit of analysis**

Disaster resilience is often allocated to technological units and social systems. In smaller scales like when we consider critical infrastructures, the focus is mainly on technological aspects. And in larger scale like when we consider the whole community, the scope will be expanded to include the interaction of multiple systems – human, environmental, and others which together add up to ensure the resiliency of a community (Renschler et al., 2010c). As column 4 of Table 1 shows, except from NIRA, which is only focused on networked infrastructures, all other seven models are at community level (Mayada, 2010). Systems diagram is developed for community level resiliency assessment and also for infrastructure networks systems. At community level, the human component is central, because in the case of a major disruptive event, resilience depends first on the actions of people operating at the individual and neighborhood scale. Community resilience also depends heavily on the actions of different levels of government and its agencies at the local and regional scales when a disruptive extreme event occurs.

In general PEOPLES Resilience Framework is based on basic community organizational units at a local (neighborhoods, villages, towns or cities) and regional scale (counties/parishes, regions, or states). Thus it can be considered as a multi scale model like ResilUS which is scalable to any number of neighbourhoods or socio-economic agents, and community. Among these community level models, URF and CDRI use city as their unit of assessment while DROP and CDRF model’s unit of analysis is county. They have chosen county as a reasonable unit of analysis mainly because of easy data availability and because it is where hazard mitigation plans and risk reduction programs are directed in the US (Mayunga, 2009).
Dynamics
Resilience can be considered as dynamic quantity that changes over time and across space. The conditions defining resilience are dynamic and ultimately change with differences in spatial, social, and temporal scales (Renschler et al., 2010a). A society may be deemed as resilient to environmental hazards at one time scale (e.g. short-term phenomena such as severe weather) due to mitigation measures that have been adopted but not another (e.g. long-term such as climate change). The temporal scale at which resilience is measured is an important issue, since it will affect the selection of variables and parameters in index construction. Although resilience is a dynamic process, but for measurement purposes, it is often viewed as static phenomena (Cutter et al., 2008a). In all eight models, there are signs which indicate the dynamic or quasi dynamic nature of the models. For example the post-event processes embedded within the DROP model allow the conceptualization to be dynamic, yet the antecedent conditions in this model can be viewed as a snapshot in time or as a static state (Cutter et al., 2008b). In PEOPLES model the community resilience indices are integral of the geospatial – temporal functionality of components of resilience. And it is supposed to continuously measure and monitor the functionality of the systems over time (Renschler et al., 2010a). The closed loops in systems diagram and iterative processes of diagnosing vulnerability, planning and implementation indicate the requirement for an iterative dynamic process to achieve a higher level of resiliency in systems (Bruneau et al., 2003). Dynamic of ResilUs is represented by pre/co-event and post-event models. For a particular dynamic (time-based) output, each model state is calculated as a comparison between a uniform random number and the aggregation of all input variables (Miles and Chang, 2011).

Data requirement
Researchers in this area often meet the difficulties in gathering data on resilience indictors for input into their models (Cutter et al., 2008a). However the availability and accessibility of the data has been one of the most important criteria for indicator construction (Mayunga, 2009). In general, data for these models fall into four types: case studies, insurance claims, direct measurements, and survey methods (Gilbert, 2010).

A huge part of the data for these models, particularly in DROP, URF, CDRF and CDRI primarily comes from the secondary datasets such as census (Cutter et al., 2008b, Tyler et al., 2010b, Mayunga, 2009, Shaw, 2009). The PEOPLES resilience framework requires the combination of qualitative (like pre/post disaster detection analysis; object oriented classification; change detection analysis of RS imagery) and quantitative data sources at various temporal and spatial scales (like voters registration, mortgage rates, saving rates, court reports, crime reports,…), and as a result, information requires to be aggregated or disaggregated to match the scales of the resilience model and the scales of interest for the model output (Renschler et al., 2010c). On the other hand, in ResilUS because of the large number of model variables and their interrelationships, the behaviour of this model is complex and it needs more simulated, aggregated and micro-data in addition to census data. However, its modularity helps to substitute a data source for a model reference. For example, rather than modelling lifeline restoration, actual lifeline restoration time-series data can be used (Bruneau et al., 2003).
Table 1. Summary of the main properties of the models

<table>
<thead>
<tr>
<th>Disaster resilience model</th>
<th>Developer/ Affiliation</th>
<th>Components</th>
<th>Scale/Unit of analysis</th>
<th>Methodology</th>
<th>Data sources</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>DROP</td>
<td>Cutter et al. HVI- University of South Carolina/ 2008</td>
<td>Social Technical Economic Organizational</td>
<td>Community/ county</td>
<td>Spatial mapping; Weighting; aggregation; Multivariate analysis; Sensitivity Analysis</td>
<td>Census; American community survey</td>
<td>Information gathering Comparison of the resiliency of different counties</td>
</tr>
<tr>
<td>PEOPLES</td>
<td>Renschler et al. MCEER- University at Buffalo/ 2010</td>
<td>Population &amp;demographics Environment Organized governmental services Physical infrastructures Lifestyle &amp; community competence Economic development Social cultural capital</td>
<td>Community (can be adapted to multi scale)/county</td>
<td>Spatial (time dependent community functionality maps); Visual inspection of RS imagery; quantitative and qualitative models for any or a combination of dimensions. E.g. SoVI for social resilience.</td>
<td>Census ; Quality of life surveys; Utility usage; Mortgage rate; Voter registration; Home price indices; Unemployment rates; SEC filings; Content Ground trothong interviews; pre/post disaster detection analysis; Object oriented classification; change detection analysis</td>
<td>Information gathering; Comparison of resilience between Counties; Empowerment of people; After complete development, it can be used as a geospatial and temporal decision support software tool</td>
</tr>
<tr>
<td>Systems Diagram</td>
<td>Bruneau et al. MCEER- University at Buffalo/ 2003</td>
<td>Conventional systems System assessment and actions Resilience assessment</td>
<td>Community level, infrastructure networks</td>
<td>Scenario based resilience assessments</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>ResilUS</td>
<td>Miles &amp; Chang et al. University of British Columbia &amp; MCEER/ 2007</td>
<td>Recovery module Loss estimation module</td>
<td>Scalable to any number of neighbourhoods or agents/PUMA (Public Use Microdata Areas)</td>
<td>Spatial; probabilistic methods; Spread sheet-based Fragility Curves to model loss; Markov chain to model recovery; Survey based assessment</td>
<td>Poll results; general observations from previous studies; Zip Code Business Pattern data; Surveys from previous studies; some simulated data; Public use micro data series; USGS shake map data</td>
<td>Information gathering; education, training, public awareness; Resilience Comparison between different</td>
</tr>
<tr>
<td>CDRF</td>
<td>Joseph Mayunga HRRC - Texas A&amp;M University/ 2009</td>
<td>Human Capital Social Capital Economic Capital Physical Capital</td>
<td>Regional/ County</td>
<td>Spatial; GIS based Composite indicators; Correlational analysis; Regression analysis; Incremental validity</td>
<td>Census, Insurance datasets; County business patterns; Spatial Hazard Events and Losses database for US (SHELDUS); US Fire administration.; Centre for Disease control and prevention(CDC)</td>
<td>Information gathering; Enhancement local community coping capacity; comparing disaster resiliency of communities; operationalize the disaster resilience concept to support planning, management and decision making</td>
</tr>
<tr>
<td>CDRI</td>
<td>Rajib Shaw &quot;Human Security Engineering for Asian Megacity&quot; of Kyoto University/ 2009</td>
<td>Physical Social Economic Institutional Natural</td>
<td>City</td>
<td>Non spatial; Spreadsheet – based; Questionnaire survey</td>
<td>Surveys; Secondary data</td>
<td>Information gathering; Priority setting and policy recommendations based on level of resiliency in each dimension;</td>
</tr>
<tr>
<td>URF</td>
<td>StephenTyler Marcus Moench Jo da Silva ARUP + ISET/ 2009</td>
<td>Urban Systems (ecosystem, infrastructure, institutions, knowledge) Social agents</td>
<td>City/ Wards (communes)</td>
<td>Shared Learning Dialogues(SLD) workshops; GIS enabled sampling and aggregation method; Hazard, Capacity and Vulnerability Assessment(HCVA)</td>
<td>Identification of homogeneous socio-economic clusters by satellite imagery verified with rapid ground survey; Secondary data</td>
<td>Information gathering; Interpretation; Collaboration; implementation</td>
</tr>
<tr>
<td>NIRA</td>
<td>Omer, Mayada Stevens/Institute of Technology/ 2010</td>
<td>Urban Network Systems</td>
<td>Infrastructure networks</td>
<td>Spread sheet-based; System mapping; Network flow analysis; Disruption scenarios</td>
<td>State of New York department of Transportation; Highway capacity manual</td>
<td>Resiliency assessment; Resilient strategy evaluation</td>
</tr>
</tbody>
</table>
Validation and operationality

Many researches in developing composite indices in resilience studies, fail to empirically validate the measures especially in terms of incremental validity. This is one of the major flaws of using composite indexes as there is no simple way to get scientific validation of a particular index (Davidson and Shah, 1997). The absence of validation is a major concern. In many circumstances, the index relies on empirical data that is far from perfect. Many assume that because numbers have been derived using some basic statistical procedure, the overall results of the index is valid and reliable. However, some qualitative methods such as in-depth surveys and case studies can be used to validate the index. Actually the best way that any sort of metrics related to the disaster field could be validated would be to continually test them after major events and refine them accordingly. This would take a considerable amount of time (Simpson and Katirai, 2006). Chang and Miles for example, have had several attempts like this to validate ResilUS (Chang, 2010, Miles and Chang, 2008). It has been applied for modeling recovery of Kobe after 1995 earthquake (Chang, 2010) and also1994 Northridge earthquake disaster (Miles and Chang, 2008) in order to calibrate several output variables with empirical data. ResilUS is currently being developed to better represent socio-cultural, personal, and ecological capitals to assist in modeling the resilience of the Gulf Coast area of Louisiana in association with the 2005 Hurricane Rita disaster (Miles and Chang, 2008).

NIRA, CDRI, URF have not been scientifically validated. However, NIRA has been applied to four types of critical infrastructure systems. These case studies probe the resiliency of the studied infrastructure systems in the face of specific disruptive events: telecommunication, transportation, maritime transportation and organizational networks. CDRI and URF has been applied to relatively 9 and 10 Asian cities for measuring their resiliency and providing some policy recommendations based on their expected level of resiliency (Shaw, 2009, da Silva and Moench, 2010).

Among all models, CDRF as a PhD project has had a full internal model validation process for its content by construct validity, predictive validity and reliability validity and plausible results were obtained (Mayunga, 2009). Based on our recent email contact, Cutter et al. are validating DROP through a case study from Mississippi Gulf Coast. PEOPLES has been partially applied for 2010 Haiti earthquake (Landscape-based Environmental System Analysis and Modelling, 2012).

Actual and potential applications

Considering the range of issues facing communities in the event of disasters, the spectrum of applications which can be addressed by current models is not broad. These issues can be categorized into two major groups in loss reduction and quick recovery after disaster (Gilbert, 2010). The resiliency models can be utilized to assess the strategies, actions and policies for loss reduction and recovery acceleration through different scenario development or by modifying land use plans and building control arrangements. This can help to not only mitigate the exposure but also to maintain functioning of the urban system during and after a disaster (Coaffee, 2008, March et al., 2011)
PEOPLES, CDRF, DROP and CDRI by quantifying the disaster resiliency and generating hotspot maps or diagrams provide the ability to compare communities with one another in terms of their resiliency, and determining whether individual communities are moving in the direction of becoming more resilient in the face of various hazards. In general, the disaster resilience determinants identified in these models, can be utilized to analyze the resiliency of each place and find the weaknesses and strengths to enhance the resiliency of place (Mayunga, 2009, Renschler et al., 2010a, Cutter et al., 2008a, Shaw, 2009).

However in ResilUS, the model’s limitations make it more appropriate for education, training, and public awareness purposes rather than the actual planning purposes (Miles and Chang, 2011). On the other hand, URF seems to be more practical framework for resilience planning which in conjunction with SLD’s (Shared Learning Dialogue) framework integrates resilience thinking into planning procedures in order to enable the vulnerable groups to anticipate, respond to and recover from projected climate change impacts. It will also provide resilience-related information to state and local mission partners that will support their risk-based resource decision-making process (Tyler et al., 2010a). NIRA by investigating the reaction of the networked infrastructure systems to disruptions, allow the decision makers to investigate the different resiliency strategies by adopting different scenarios.

Practicality of the resiliency quantification results depends on the level and scale of the assessment. At larger scale it is limited to public awareness and education. At regional scale, on the other hand, it can be more useful for disaster managers and policy makers to direct the resources to most vulnerable areas and where management and planning actions are needed. Resiliency models at local level by identifying more contextual determinants of resiliency of place can provide a tool for urban designers and planners to assess their designs and plans in terms of their resiliency. Several studies (Allan and Bryant, 2011, Bryant and Allen, 2011, March et al., 2011) suggest that the resilience is linked to the built environment indicators on spatial morphologies that encourage response and adaptation, such as a diversity of open spaces, redundancies in connectivity, self-sufficiency (food from urban gardens, multiple sources of water) and local urban spaces that can quickly be adapted to encourage communication and response. They note that recovery also has a spatial dimension and resilience theory suggests that design, form and space, as well as, process could influence recovery.

**Conclusion**

This paper has analyzed some of the most well cited and prominent resiliency models. Resiliency is a broad and complex concept which is very difficult to define and measure comprehensively. This review revealed that most of the frameworks for measuring disaster resiliency are generic and broader in the context of environmental hazards. Defining a proper context and scale for resiliency models seems necessary to take the most useful and applicable output of the model and also to provide a consistent basis for data development required for assessment. More specifically the variables and attributes of some of the frameworks are very broad and often not workable at the community level for measurement purposes. Therefore their application becomes clumsy at this level particularly where availability of data for certain indicators at the local level is a great challenge. The existing
indicators can also be criticised for difficulty of meaningful interpretation or the lack of causal linkages between the indicator values and the policy relevance of outcomes.

This critical review also points out a number of gaps in measuring disaster resilience literature. First, a large portion of the resiliency literature is mostly conceptual with excessive emphasis on resilience in socio-ecological systems. In this context, there remains a lack of robust case studies which can test or validate the models and their theories. Second is the lack of policy relevancy of the outputs. In this regard, the potential applications which were mentioned in earlier parts of this paper deserve more attention by researchers in this field including specific urban design and planning measures which can influence the resiliency of place such as incorporating flood attenuation as part of an integrated urban form. Open spaces, such as recreational parks and ovals to manage and reduce potential flood hazards and other applications such as improvement in construction practices, building codes, and mitigation of homes (retrofitting or elevating) are measures that enhance resilience as is the building of redundancy in critical infrastructure and also acting as a management or decision making tool are seem to be in reach by further developing and integrating the existing frameworks. To sum up, for making our communities disaster resilient we need tools for evidence-based policy making, analysis and evaluation of a large variety of issues and criteria. Existing experience shows that developing indexes, typology approaches and benchmarking can be of great help in research as well as for practitioners for making our communities resilient.

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Exploring a Methodological Framework for Understanding Adaptive Change in Cities

Darren Nel¹, Chrisna Du Plessis² Karina Landman³

Abstract

Resilience is about change and how systems respond to change. To understand resilience it is therefore important to understand how cities respond to change. Cities can be described as social ecological systems that react to change and perturbations through responses at various spatial and temporal scales. In the study of resilience of ecosystems, this is described through the concept of panarchy and the metaphor of the adaptive cycle. The adaptive cycle is used widely as a key metaphor to describe resilience. Central to this metaphor is the idea that systems undergo periodic cycles of change without fundamentally changing functional identity, remaining within a particular basin of attraction. However, internal or external pressures may also cause the system to tip into another basin of attraction or system state, with a different functional identity.

In ecosystems, these different states are well described and the characteristics indicating a change in identity are well defined. However, in the study of urban social ecological systems, this is still a mainly unexplored topic and the methodologies for identifying and mapping different urban system states and phases within the adaptive cycle, let alone the application of the adaptive cycle concept requires further investigation.

This purpose of this paper is to present a proposed a methodological framework for describing the movement of cities or neighbourhoods through the various phases of the adaptive cycle and possibly, different system states. This method is illustrated using the example of two neighbourhoods in South Africa and the changes they experienced over a period of approximately one hundred years.

Keywords: Resilience, Panarchy, adaptive cycle, urban systems.

1. Introduction

Cities, like ecosystems, are complex adaptive systems (Holland, 1996; Gunderson and Holling, 2002; Johnson, 2002; Taylor, 2005; Davoudi et al., 2012). As a great deal of work on resilience has been done on the study of ecosystems, and social-ecological systems

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it would seem only appropriate that in our quest to understand urban resilience that we build on and apply the thinking and concepts that have already been developed within this field. However, unlike ecosystems, the processes and methodologies for describing urban systems and the way they change have not been fully explored. Such exploration is necessary as resilience in the urban environment may mean something different to resilience of an ecosystem. This paper aims to explore a possible methodological framework to map adaptive change, based on the concept of panarchy and the metaphor of the adaptive cycle. This framework was developed while reflecting on previous studies of two neighbourhoods in Tshwane that the authors have undertaken.

2. Background to key resilience concepts

2.1 Panarchy

Among the most notable of theories that describe resilience of social-ecological systems and explain how these systems naturally change and evolve is the concept of panarchy and the metaphor of the adaptive cycle introduced by Gunderson and Holling (2001). The concepts behind the panarchical view of social-ecological systems as described by Gunderson and Holling (2001) are:

1. Social-ecological systems should be treated as complex adaptive systems in which the various agents are constantly adapting to the changes within their environment. Due to the interactions by the various components the system may produce unpredictable behaviour.

2. A system can have more than one stable state instead of a single point of equilibrium. Change can still happen within each stable state; however a few, normally three to five, important variables and interactions remain the same. A system with more than one stable state can move quickly between states when a critical threshold or tipping point is reached. A prime example of this is the cycles of growth and recession that happen within an economy.

3. “Panarchy emphasizes the importance of relevant interactions across geographic and time scales” (Gunderson and Holling, 2002, p3). This highlights the importance of a system’s history as well as that a system interacts at higher and lower spatial scales, also referred to as nested systems. Systems at higher scales tend to move at a slower rate though the adaptive cycle than those at the lower scales. “In panarchies transformational change can be generated from below or from above. At the same time larger, slower levels can act to reinforce and sustain the panarchy” (Gunderson and Holling, 2002, p25).

The concept of panarchy still needs to be tested on urban systems. The Resilience Alliance 2010, p30) suggested that the city be seen as the focal scale, with neighbourhoods forming sub-systems, and one can add, within neighbourhoods the streets or buildings forming sub-systems of the neighbourhoods. This understanding comes from the practice of defining large ecosystems such as a watershed as focal scale. However, the complexity of the city
and the diversity in its smaller sub-systems suggest that for urban resilience it would be more practical to look at a smaller scale such as the neighbourhood or city district as focal scale.

2.2 The Adaptive Cycle

The metaphor of the adaptive cycle is used to describe the movement of a system through four distinct phases typically followed by social-ecological systems. The various phases of the adaptive cycle are: Growth (r); Conservation (k); Release (Ω) and Reorganisation (α) and are described in further detail in Table 1 below.

Table 1: A summary of the characteristics of each phase of the Adaptive Cycle as described by (Gunderson and Holling, 2001, 2002; Folke, 2006; Davoudi et al., 2012)

<table>
<thead>
<tr>
<th>Phase of Adaptive Cycle</th>
<th>Characteristic of each phase</th>
<th>Level of Resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>r Growth</td>
<td>This phase occurs early in the cycle and is characterised by a period of rapid growth, and an accumulation of resources, as ‘agents’ (often innovators or entrepreneurs) seizes opportunities after a disturbance and make use of this time to exploit new niches. The system components are weakly interconnected with little or no internal regulations. There is an increasing degree of diversity; however the system is more vulnerable and far more easily influence by external variability. The agents (individuals) that function best in this phase are those that are best “adapted to dealing with the stress and opportunities of a variable environment – the risk takers, the pioneers, the opportunists”(Gunderson and Holling, 2001, p 43). These agents typically operate at a local scale and over short time periods.</td>
<td>High, but decreasing</td>
</tr>
<tr>
<td>k Conservation</td>
<td>The transition from the r phase to the k is a slow incremental process that happens as resources begin to accumulate (as the system moves closer to the k phase its growth rate slows). The connections between the different agents increase as the system moves towards a more regulated but stable state. The increase in stability comes at a cost as the system is only able to deal with a decreasing range of situations. The agents that reduce uncertainty are now favoured over those that functioned better in a variable environment. The shift from the k to the Ω (Release) phase can happen at any time as the system is now more vulnerable to shocks.</td>
<td>Low</td>
</tr>
<tr>
<td>Ω Release</td>
<td>When a system transitions into this phase it is usually rather sudden and happens when a disturbance pushes the system past a particular point or threshold. The resources that were accumulated during the k phase are now released as the strict regulations and interconnectedness of the system is now broken. This continues until the disturbance has dissipated.</td>
<td>Low but increasing</td>
</tr>
<tr>
<td>α Reorganisation</td>
<td>The shift from Ω to α is characterised by the system having weak internal controls; the opportunity for innovation; high potential. However there is a large degree of uncertainty and a reorganisation of the system’s structure. The system is also easily influenced by external factors which can lead to renewal or collapse of the system.</td>
<td>High</td>
</tr>
</tbody>
</table>

*An agent can be an individual, household, firm, organisation, government, etc.

The concept of the adaptive cycle falls within the lager concept of panarchy whereby social-ecological systems form sets of nested adaptive cycles that operate at varied scales. The
larger scales tend to have slower cycle speeds while the lower, smaller scales, tend to have more rapid cycles through the adaptive cycle (Gunderson and Holling, 2001; Folke, 2006; Resilience Alliance, 2010). It is by examining how systems undergo these changes and their behaviour at the various phases that we may begin to better understand resilience in general and more specifically, urban resilience. It is also important to note that “transitions between the four phases of the adaptive cycle do not always follow the same sequential pattern” (Resilience Alliance, 2010) as described by the adaptive cycle. Some systems may skip a phase completely and move onto the next or even go back to the previous phase (Resilience Alliance, 2012).

2.3 What has been done before

The Resilience Alliance (2010) has developed a workbook for assessing the resilience of social-ecological systems that draws on insights derived from complex adaptive systems and concepts such as panarchy and the adaptive cycle. This workbook provides a process to assess the resilience of a particular function of a system or sub-system. It is based on the development of a conceptual model of the social-ecological systems being studied, with the intention of identifying critical thresholds between different system states. To develop the conceptual model the assessment process uses an issue based approach to a) focus the assessment; b) determine the boundaries of the focal scale, and c) identify critical stakeholders and elements. It further uses the tool of historical narrative to map the movement of the system through phases of the adaptive cycle, as well as identify disturbances, cross-scale (spatial and temporal) interactions, different possible system states and the variables that determine these states and which point to the thresholds between states. However, there are a number of uncertainties that are not yet resolved in a satisfactory manner, especially as concerns its use in urban systems. The primary focus of the assessment process is on ecosystems and the effects of human systems on the environment and vice versa, and therefore the examples that have been used are rooted in ecological science and or disaster risk reduction. There is very limited guidance on how to address the concerns of urban resilience, with the urban environment being evaluated as an integrated system. In particular, the workbook does not provide adequate guidance on how to identify the key elements, drivers and agents, especially within the urban system. As practitioners continue to engage with the assessment workbook, more of its shortcomings are exposed and gaps in understanding are bridged. Haider et al, (in Davoudi et al, 2012, p 317), suggest a number of ways to improve the usefulness of the workbook, one of them being a larger diversity of examples of how the resilience assessment has been used. This paper (and the studies on which it is based), attempts to contribute to the development of the assessment process by including the urban social-ecological system. What we are suggesting is not an assessment framework, but rather a process for understanding the adaptive change cycles that an urban area undergoes and the forces that shaped the study areas, so as to discover the key elements, drivers and agents within the urban system being studied. As such it is seen as another tool in the larger assessment framework proposed by the Resilience Alliance workbook.
3. A Proposed Methodological Framework for Understanding Adaptive Change within Cities

The methodological framework that is being proposed was developed through deliberation of the processes that the authors have developed while investigating urban systems and their resilience. Its theoretical base stems from the rationale that the urban environment is a complex adaptive system, and the concepts of panarchy and the adaptive cycle as a primary means to describe changes that systems undergo. Although the panarchical and adaptive cycle concepts have been developed for use for social-ecological systems (Gunderson and Holling, 2001), with the focus being on the ecological system, we believe that these concepts can be adequately translated to describe the urban system.

As discussed, cities are a particular subset of social-ecological systems and any method that seeks to assess or understand their resilience needs to look at the integrated urban system, considering the interactions between not only its ecological and socio-economic systems, but also its spatial and physical attributes and the requirements of community resilience. Furthermore, it should be able to deal with the diversity of its sub-systems and with the complexity and sheer amounts of data that is required. The complexity of the issues means that the rule of hand often cannot capture the critical dynamics at the scales where social and individual resilience come into play and where the tensions between remember (the slow-changing spatial and institutional structures) and revolt (critical self-organization at neighbourhood scale that combines to change or threaten the larger scale functions of the city, e.g. enclosed neighbourhoods or service delivery protests destroying infrastructure) creates the greatest dangers for tipping the system into another system state.

We are proposing that for urban resilience the appropriate focal scale should be at the level of neighbourhood or city district as the level that sits between the self-organising activities of individual agents (households, businesses) that ultimately shapes the structure and functions of the city, and the larger urban system that provides the slow changing variables. This brings in the multiple scale perspective that lies behind the idea of the panarchy. Furthermore, because a “city is a kind of pattern-amplifying machine: its neighbourhoods are a way of measuring and expressing the repeated behaviour of the larger collective… [as] those patterns are fed back to the community, small shifts in behaviour can quickly escalate into larger movements” (Johnson, 2002, p40). The neighbourhood forms a subsystem of the larger city system while the street and site level form subsystems of the neighbourhood system.

The case studies that we will use as examples are based on a study completed in 2011. This study explored spatial change and the drivers behind it within the context of a South African neighbourhood. We have reinterpreted and added to the data from the original study in order to begin to look at how neighbourhoods go through a cycle of adaptive change. Throughout the description of the proposed framework, reference will be made to previous studies in the form of examples as well as part of the reflective process of what has been done.

The two case studies used were of Lyttelton Manor (Lyttelton) and Irene, both in the former town of Centurion that now forms part of Tshwane (Tshwane is the municipal area that
includes Pretoria). These neighbourhoods are located in close proximity to each other but have developed very differently over the past one hundred years. The studies involved a historical overview of the development of the two neighbourhoods, and considered social, economic and institutional factors that played a role in shaping their spatial structure. The findings of the studies suggested that, in the case of these two neighbourhoods, the availability of water, the community attitude to development, location in relation to employment centres as well as to services and retail facilities that are in close proximity are amongst the principal forces that have shaped these neighbourhoods (Nel, 2011). The findings further indicated that no one specific factor can be attributed to having the largest effect of transforming these neighbourhoods spatially. It was rather a combination of different factors, and the interaction between them that occurred at different times and scales, throughout the history of the two neighbourhoods that influenced them. This confirms the idea that one needs to consider the urban environment holistically as a complex adaptive system. However, due to the nature of the studies no ecological data was included. Future studies should take this into consideration.

3.1 Towards a Methodological Framework for studying adaptive urban change

This section outlines the methodological framework used. This framework builds on the Resilience Alliance assessment process (2010), but adapts it to suit the urban system. Examples will be given from the mentioned case studies to help the reader understand and to help support the concept.

Step 1: Select a focal area and set boundaries

To begin an assessment the study area must be selected and boundaries must be set (Resilience Alliance, 2010, p10). Boundaries are placed in order to maintain the focus on the focal area. The bounding of the focal area becomes increasingly important as systems are open to their environments and rarely have clear, well defined, boundaries (Meadows, 2008; Innes and Booher, 2010). The boundaries that are applied should be not only over space but time as well. They should take the form of soft/porous boundaries; which acknowledge that there are cross scale interactions and that systems cannot be cut off as they are open to outside influences. The boundary is placed as a means to keep the study practical. Setting boundaries is up to the discretion of the observer and may have to be adjusted to include or exclude some particular aspects as the assessment is carried out;. This is a very iterative process. For the case studies the existing boundaries of the two neighbourhoods were used, as they were already well defined (see Figure 1).
Step 2: History of the focal area

Once the boundaries have been delineated for the study, the second phase of the framework is to compile a history or timeline of the focal system. A system's history matters, as its present and future behaviour are largely due to its past (Cilliers, 2000; Geyer and Rihani, 2010). As we will illustrate, the history of the system will begin to allude to the system's resilience. Developing such a timeline needs to consider various sources from the different physical, institutional and social systems at play. Throughout this process it is important to begin to identify spatial and temporal patterns that repeat themselves. The history of the focal system should be done as far back as possible, while remaining plausible and relevant to the study.

A one hundred year period was selected for the case studies as this was when the two neighbourhoods were established. There was also sufficient historical information available to allow for a study over this length of time.

Step 3: Identification of key events and changes

The next phase is to begin to look for ‘frozen accidents’; events which have inadvertently set the system on a specific path or become an underlying part of that system which in turn shapes the system’s current and future behaviour (Holland, 1996; Gunderson and Holling, 2001; Geyer and Rihani, 2010). Once a ‘frozen accident’ has been identified it is important to describe the circumstances that created it, as this will allow for a better understanding of the drivers of change. The changes and events, as well as their impacts, will begin to guide the study in identifying the relevant information needed to describe the events and subsequent changes that form part of the systems history. The relevant data that will be needed for the study will begin to ‘emerge’ from the systems history. To help with this it may be useful to look at the timeline through various ‘lenses’, i.e. social, economic, spatial, institutional, etc. The different lenses bring different types of changes and events into focus.

Step 4: Multiple scales:

A panarchical view requires that, significant events and changes that have happened at a higher and lower spatial scales, i.e. city, street, national or international scales, be added to the focal scale timeline. This is important because lower and higher scales within the panarchy will have an effect on the focal system (Gunderson and Holling, 2002; Resilience Alliance, 2010). From the case studies, an example can be given where the combination of economic recession in the 1980s, due to sanctions posed on South Africa, as well as an aging white population, had a large effect on Lyttelton leading to a large number of subdivisions within the neighbourhood (Nel, 2011)

Step 5: Distinction between changes

Within this step the identification of the various characteristics that have changed, and when these changes have happened, will be needed. This should be done by firstly distinguishing the changes and events according to the magnitude of the effect that they had on the system. These groupings can be defined as small, medium and large events/changes (this should be done in terms of what the long term effects of that event/changes were on the
system or, for more recent events, what the perceived long term effect will be). Secondly, these events/changes are differentiated into categories or types of change, i.e. social, economic, spatial, and institutional. Some events may fit into more than one of these categories, which may also fit into different levels of magnitude, i.e. the decision of the community of Lyttelton to decide against having small blocks with internal roads during an urban renewal process was a ‘small’ social event, however it had a significant ‘large’ long term effect on the physical and spatial nature of the neighbourhood.

From the differentiations between magnitude of change and type of change a new series of timelines can be created, were the history of the area has been divided into various separate components. These timelines also represent specific change within the system. This part of the process is to ensure an understanding of the events and changes, and how these may affect more than one category, i.e. spatial and ecological, and possibly various scales of impact. Figure 2 illustrates an example of how this can be represented using the two neighbourhoods changes as an example.

**Step 6: Combine timelines**

In order to understand the system wide changes that have occurred, as opposed to the specific changes, the various timelines are now reconstituted into a new ‘combined’ timeline.
that explores the events from different perspectives. During this process, as in the cases of Lyttelton and Irene, key events that had major effects on the system begin to become apparent. These key events point to tipping points or frozen accidents that have profoundly impacted the course of the systems history and the nature of its behaviour.

Figure 3 shows an example of how the original timeline can be recombined with the ‘new’ timeline; the example only shows a short period of the two neighbourhood’s timelines. The key events have been separated into their different characteristics and magnitudes of change that were determined previously. The value of this part of the process is that it helps to show that over the course of a system’s history various events from the past have a long term effect on the system and that during some periods there may be many different events and in other times there may be only a single small event. This new timeline will also be vital in determining the weight of each event/change has in the overall movement of the system though the adaptive cycle.

**Step 7: Adaptive change though a systems history**

![Figure 4](image-url)

*Figure 4: A representation of changes and movement of Lyttelton and Irene through the adaptive cycle with key events and changes being indicated as well as when they occurred. Adapted from Landman and Nel (2012, p9)*
The adaptive cycle is now brought back in to focus as the means to describe change, as well as the characteristics of that change in terms of the systems resilience. Reconsidering Table 1 and looking at the characteristics of each phase of the adaptive cycle, one can now compare them to the system’s general timeline of change; using the systems history to identify and ‘match’ the various stages of the adaptive cycle. By using the identified differentiation between the magnitudes of the long term effects, its gives guidance to which events have more weight and provide a greater pull or push factor in moving the system though any particular phase of the adaptive cycle.

Table 2 shows the simplified movement of Lyttelton and Irene though the adaptive cycle where Figure 4 shows a stylised version of the movement of the two neighbourhoods through the adaptive cycle, with the key events that have moved or halted progress the system through the adaptive cycle indicated for each of the neighbourhoods.

The value that Figure 4 adds is that allows us to visualise the movement of the system through the adaptive cycle, which in turn, begins to help to understand how some key events can greatly affect the system’s movement though the adaptive cycle as well as the long term behaviour of the system. Understanding how systems adapt to changes may help us to better understand and manage change in the future.

Table 2: The development of Irene and Lyttelton in terms of the adaptive cycle

<table>
<thead>
<tr>
<th>Phase</th>
<th>Irene</th>
<th>Lyttelton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth – r</td>
<td>1900s – 1960</td>
<td>1900s - 1940s</td>
</tr>
<tr>
<td>Conservation – K</td>
<td>1960s – Present</td>
<td>In the late 1970s</td>
</tr>
<tr>
<td>Release - Ω</td>
<td>Not happened yet</td>
<td>1980s</td>
</tr>
<tr>
<td>Reorganisation - α</td>
<td>Not happened yet</td>
<td>Late 1980s - 1990s</td>
</tr>
<tr>
<td>Growth – r</td>
<td>Not happened yet</td>
<td>1990s</td>
</tr>
<tr>
<td>Conservation – K</td>
<td>Not happened yet</td>
<td>2000s</td>
</tr>
</tbody>
</table>

4. Conclusion

In searching for a method to describe resilience and how complex adaptive systems go through a process of adaptive change, we have considered the Resilience Alliance’s existing and well used approach contained in the ‘Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners’. We found the concept of panarchy and the metaphor of the adaptive cycle useful tools to describe changes within the urban environment.

However, the methodologies available are not yet adequate to describe the urban system and all its complexities as an integrated social-ecological system. The Resilience Alliance’s workbook is also not clear enough as to how to identify the key elements, drivers and agents, especially within the urban system. To bridge this gap we have developed a methodological framework for identifying key drivers, events and agents and how these push or pull the urban system being studied through the phases of the adaptive cycle. We have proposed that the appropriate focal scale would be the neighbourhood and that by
comparing the changes in adjacent neighbourhoods, it will also be possible to identify the elements, drivers and agents at higher system levels. This method still needs to be tested further on different scales as it may not be appropriate for different scales other than on the neighbourhood level.

Throughout the study there were many challenges. One of the biggest being the challenge of translating the language and concepts of panarchy and adaptive cycle, and the associated terminology, that comes from the field of ecology, into the concepts and language used within the built environment. This is not just a matter of applying terminology to a different type of ecological system (the social-ecological system) or a translation of language. For resilience thinking to become a truly useful concept for the planning and management of urban systems, what is required is a translation of concepts.

Acknowledgements

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References


Abstract

The severity and economic implication of the recent Canterbury earthquake disaster in New Zealand and continual reticence of building owners living in earthquake-prone buildings showed that property owners are unwillingness to adopt appropriate earthquake risk mitigation measures. This unwillingness suggests that the earthquake mitigation information provided and communication strategies may have been ineffective for making informed mitigation decision. This study examines the relevance of mitigation information provided and the efficacy of existing and emerging communication strategies for making informed risk mitigation decisions. Data were collected using structured questionnaire from property owners of earthquake-prone buildings. This study identifies seventeen significant strategies, clustered under five categories that may contribute to successful earthquake risk mitigation in New Zealand, specifically for retrofitting earthquake-prone buildings. These strategies include the provision of a unified safety assessment information system, mandatory disclosure of seismic risks and the use of novel approaches such as the social networks, mass media, reiterating past earthquake experiences and public recognition of pro-social mitigation behaviour are paramount. Subsequent review and adoption of these strategies could communicate relevant risk information to all stakeholders involved in earthquake risk mitigation, leading to informed risk mitigation decisions.

Keywords: Earthquake-prone buildings (EPBs), Earthquake risk information, Communication strategies, Mitigation decisions
1. Introduction

Given the recency and severity of the Canterbury earthquakes swarm in New Zealand since 2011, it is not surprising that seismic hazard and disaster is a frequent topic of conversation among the residents, visitors and media. According to Paton and Johnston (2006), frequent thought, discussion and information receipt about earthquake risks is necessary to propagate the awareness of earthquake risk and assist people to make decisions and work towards the adoption and implementation of appropriate risk mitigation measures. Likewise, the availability of relevant earthquake mitigation information, and the means of communicating and disseminating this information to property owners and the public, are significant parameters that can be used to influence desired decisions regarding risk mitigation (Keeney and Winterfeldt, 1986; MacGregor et al., 2008). However, the continual reticence of building owners living in earthquake-prone buildings (EPBs) to retrofit their EPBs suggest that the present risk mitigation information provided and communication strategies are ineffective for enhancing their decision to improve the level of earthquake risk mitigation in New Zealand. The aim of this study is to investigate relevance of risk mitigation information provided, and the effectiveness of existing and emerging communication strategies necessary to enable informed risk mitigation decision regarding seismic rehabilitation of EPBs.

2. Earthquake Risk Information and Communication Strategies

The provision and communication of adequate risk information is an important parameter when attempting to explain how people make seismic risk mitigation decision because of its primary objective of providing and sharing information about the hazard, associated risks and appropriate mitigation measures (Paton, 2006). According to Neuwirth et al. (2000), the provision of appropriate information about seismic risks and the efficacy of mitigation measures should produce greater rates of willingness to adopt protective measures. Likewise, Lindell and Perry (2004) explained that in order to yield desired outcome of improved earthquake risk mitigation, an effective natural hazard information provision and communication program should consider good quality of information provided, credibility of information source, means of communication and the management of the whole communication process.

Earthquake risk information can be communicated through both informal and formal channels. Several traditional approaches such as printed brochures, warning letters to property owners, regulatory requirements and penalties have been used in communicating earthquake risk information to the public. According to Whitney et al. (2004), conventional methods of risk communication have little influence because they are perceived to lack novelty, validity or relevance. Mileti and Fitzpatrick (1993) suggested that conventional methods of risk communication can be improved by using an alternative novel approaches for communicating earthquake hazard and risk information. In addition, previous research suggested that in order to generate an effective response from risk communication, the distribution of earthquake preparedness information and materials should include a mix of passive and proactive approaches that utilizes both traditional and emerging information technologies such as reiterating past earthquake experiences within community networks,
using mass media and policy entrepreneurs (Bourque et al., 2010; Egbelakin et al., 2011). Moreover, Paton and Johnston (2006) established that an effective risk communication strategies implemented at the community level will likely lead to risk personalisation that allows people to deliberate mitigation plans at the community level and this could lead to preparedness and are likely will enhance seismic risk mitigation decisions. However, Lindell and Perry (2004) found that providing and communicating earthquake risk information does not necessarily motivate people to adopt mitigation measures or divert significant efforts into assessing alternative sources or channels for providing risk information. A significant portion of people preferred to remain ignorant about natural hazards such as earthquake because of a failure to personalise the risk, when poor quality of information is provided, perceived credibility of information source, inadequate dissemination strategy or perceived incapability of making use of additional information (Lion et al., 2002).

Perception of credibility to the source of risk information impacts seismic mitigation decisions (Whitney et al., 2004). Earthquake risk information is provided through various sources, which include governmental authorities, media, peers, friends and family, and are judged in terms of their perceived credibility. The credibility of information source comprised of three primary characteristics; expertise, trustworthiness and past reliability in communicating risk information (Perry and Lindell, 1990). Generally, governmental authorities such as local council or government officials and earthquake risk mitigation professionals such as engineers are commonly considered as credible source of information (Mileti and Sorensen, 1988). Mass media and peer contacts have also been identified as sources that are perceived as credible. However, there is a growing awareness about the impacts of the media in communicating hazards information to the public (Scanlon, 2009). Likewise, inconsistency and disparity in risk information provided by the different risk provision sources reduce its credibility and quality of information and the ability of the information to assist in making constructive mitigation decisions (Poortinga and Pidgeon, 2004; Paton, 2007). In addition, existing research studies have suggested that using adequate risk communication approaches with sound dissemination plan to enhance earthquake risk mitigation and implementation has an advantage of simultaneously improving people’s perception regarding earthquake probability and severity, fatalistic mind sets and improving trust in the efficacy of seismic design techniques for reducing earthquake risks (Paton, 2007; Smith, 2009).

A key issue in earthquake risk mitigation concerns information acceptance, whether existing information provided is relevant and have been effectively communicated to generate enough concern and response that could enhance the likelihood of adopting mitigation measures. Despite the volume of research work on risk information provision and communication, there remains a lack of clarity regarding the provision of relevant information for making informed decision, and the efficacy of communication strategies for increasing the likelihood of property owners’ adoption of adequate mitigation measures. An investigation of novel risk information provision and communication approaches such as using the social media, public recognition, reiterating past survival stories in social events, regulatory requirements and risk communication process management, is necessary highlight the efficacy of such novel methods for improving earthquake risk mitigation.
3. Research Method

This paper reports a part of the research findings of a recently completed study undertaken to examine the relevance of earthquake mitigation information provided to property owners, and the effectiveness of existing and emerging communication approaches necessary to facilitate informed risk mitigation regarding seismic rehabilitation of EPBs. Twenty-five factors that include type of risk mitigation information provided, sources of information and communication strategies were operationalised from literature and preliminary interviews, and their level of usage and effectiveness for making appropriate risk mitigation decision was tested in fieldwork.

A cross-sectional survey research design was adopted and data were collected using an online questionnaire through Survey-monkey portal. The population frame of this study comprised identified owners of EPBs. The sampling frame comprised owners of EPBs identified after the enactment of the Building Act (2004) and who may have and have not retrofitted their EPBs, but have all been notified by their local TAs of their buildings vulnerability to seismic disasters since 2004. The sampling frame indicates that responses used in the research were directly from the study population. Respondents were mainly asked to indicate on a five-point likert scale, the extent to which mitigation information provided as well as existing and emerging communication strategies could or have helped them to make informed risk mitigation decisions. The questionnaire was pre-tested in a pilot survey before an industry wide survey was conducted. The data were entered into SPSS for analysis. Preliminary analysis conducted such as analysis of missing data and normality test was conducted for data clean-up and to fulfil normality and goodness of fit criteria. Kolmogorov-Smirnov test conducted showed that all responses to the variables are normally distribute with a p-value larger than 0.05. The mean of each variable was compared by conducting an independent sample t-test (Compeau and Higgins, 1995). A test value of 3 was used to test whether the means were significantly different from a mid-point of 3 on a Likert rating scale of 1 to 5. T-tests were used to identify effective information provision and communication strategies that are likely to enhance building owners’ decision to retrofit their EPBs. A relevant mitigation information, source of information and communication strategy is considered significant when p<0.05. Industry experts reviewed the findings for confirmation and comments to establish data validity.

4. Sample Characteristics

A total of 510 online questionnaires were administered and 208 surveys were completed representing a response rate of 40.8%. This response rate compares favourably with other studies in earthquake risk management (Ronan et al., 2001; Lindell et al., 2009). The analysis of the questionnaire provides a summary of the respondents’ profile and EPBs projects undertaken. A summary of respondents’ demographic information and a selected retrofitted EPB projects were provided in Tables 1 and 2. Information summarised in Tables 1 and 2 suggest that most of the respondents are familiar with seismic risk mitigation decision and retrofitting of EPBs projects. For instance, the respondents’ geographical distribution indicates that people residing in low to moderate and high risk earthquake prone regions are well represented in the study. Also, the majority of the projects reported are
located in high-risk regions (89%). In addition, most of the buildings have recently been retrofitted; 52% were retrofitted less than a year ago and 32% were strengthened between the last two and four years. Hence, the respondents profile and selected retrofitted EPBs projects indicate that they are well experienced on the subject matter and in a position to provide reliable information.

**Table 1 Respondents Profile**

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respondent’s Location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auckland</td>
<td>46</td>
<td>23</td>
</tr>
<tr>
<td>Wellington</td>
<td>63</td>
<td>31.5</td>
</tr>
<tr>
<td>Christchurch</td>
<td>51</td>
<td>25.5</td>
</tr>
<tr>
<td>Gisborne/Napier</td>
<td>19</td>
<td>9.5</td>
</tr>
<tr>
<td>Others: Low seismic risk region</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Others: High seismic risk regions</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Personal Experience of an Earthquake Event</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>63</td>
<td>31</td>
</tr>
<tr>
<td>Yes</td>
<td>137</td>
<td>69</td>
</tr>
<tr>
<td><strong>Years of experience in EPB Projects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5 years</td>
<td>53</td>
<td>26.5</td>
</tr>
<tr>
<td>6-10 years</td>
<td>21</td>
<td>10.5</td>
</tr>
<tr>
<td>11 - 15 Years</td>
<td>19</td>
<td>9.5</td>
</tr>
<tr>
<td>16 - 20 Years</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>21 - 25 Years</td>
<td>23</td>
<td>11.5</td>
</tr>
<tr>
<td>&gt; 25 Years</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Not Applicable</td>
<td>46</td>
<td>23</td>
</tr>
</tbody>
</table>

**Table 2 Characteristics of EPB projects handled by respondents**

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auckland</td>
<td>13</td>
<td>6.5</td>
</tr>
<tr>
<td>Wellington</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Christchurch</td>
<td>52</td>
<td>26</td>
</tr>
<tr>
<td>Gisborne/Napier</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>Others: low seismic risk region</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td>Others: high seismic risk regions</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td><strong>Period of construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior to 1935</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td>After 1935</td>
<td>44</td>
<td>22</td>
</tr>
<tr>
<td>After 1964</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>After 1976</td>
<td>15</td>
<td>7.5</td>
</tr>
<tr>
<td>After 1992</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Prior to 2004</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Building’s historic registration category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heritage Category I</td>
<td>75</td>
<td>37.5</td>
</tr>
<tr>
<td>Heritage Category II</td>
<td>82</td>
<td>41</td>
</tr>
<tr>
<td>Unsure</td>
<td>43</td>
<td>21.5</td>
</tr>
<tr>
<td><strong>Building category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Commercial</td>
<td>104</td>
<td>52</td>
</tr>
<tr>
<td>Mixed-use (commercial and residential)</td>
<td>51</td>
<td>25.5</td>
</tr>
<tr>
<td>Institutional (churches, schools)</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Others</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Most recent retrofit period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 year</td>
<td>104</td>
<td>52.0</td>
</tr>
<tr>
<td>2-4 years</td>
<td>65</td>
<td>32</td>
</tr>
</tbody>
</table>
5. Significant Earthquake Risk Information Provision and Communication Strategies

Twenty-five factors that include quality of information provided, communication strategies and source of information were investigated, and seventeen were found significant for improving seismic retrofit decision and implementation of EPBs. These seventeen factors were further clustered under five categories (see Table 3). Significant earthquake risk information provision and communication strategies within the context of the research investigation are discussed below.

Table 3: Significant Earthquake Risk Information and Communication Strategies

<table>
<thead>
<tr>
<th>Code</th>
<th>Information Provision and Communication Strategies</th>
<th>Mean</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source of Earthquake Risk Information (SRI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRI1</td>
<td>An earthquake risk mitigation Exhibition</td>
<td>2.01</td>
<td>2.76</td>
<td>0.08</td>
</tr>
<tr>
<td>SRI2</td>
<td>Earthquake risk Professionals (e.g. engineer/architect)</td>
<td>2.85</td>
<td>1.94</td>
<td>0.07</td>
</tr>
<tr>
<td>SRI3</td>
<td>Government officials</td>
<td>3.96</td>
<td>3.36</td>
<td>0.05*</td>
</tr>
<tr>
<td>SRI4</td>
<td>Family/friends</td>
<td>4.13</td>
<td>3.12</td>
<td>0.00*</td>
</tr>
<tr>
<td>SRI5</td>
<td>Mass Media</td>
<td>3.73</td>
<td>2.51</td>
<td>0.02*</td>
</tr>
<tr>
<td>SRI6</td>
<td>Lessons learnt from past earthquake experience</td>
<td>4.88</td>
<td>3.18</td>
<td>0.01*</td>
</tr>
<tr>
<td><strong>Quality of Earthquake Risk Information Provided (QIP)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QIP1</td>
<td>Provision of sufficient information about exposure to earthquake risks and efficacy of mitigation measures</td>
<td>3.01</td>
<td>4.28</td>
<td>0.04*</td>
</tr>
<tr>
<td>QIP2</td>
<td>Providing information about benefits of retrofitting</td>
<td>4.88</td>
<td>3.32</td>
<td>0.00*</td>
</tr>
<tr>
<td>QIP3</td>
<td>Information provided about earthquake risks and mitigation was easy to understand</td>
<td>3.09</td>
<td>4.88</td>
<td>0.20</td>
</tr>
<tr>
<td>QIP4</td>
<td>Provision of a unified safety assessment information system</td>
<td>4.21</td>
<td>4.28</td>
<td>0.00*</td>
</tr>
<tr>
<td><strong>Using Regulatory Requirements (RR) for dissemination information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR1</td>
<td>Implementing a building grading system</td>
<td>2.79</td>
<td>3.12</td>
<td>0.00</td>
</tr>
<tr>
<td>RR2</td>
<td>Mandatory disclosure of building seismic risks</td>
<td>3.91</td>
<td>3.60</td>
<td>0.00*</td>
</tr>
<tr>
<td>RR3</td>
<td>Comprisal of seismic risks in property valuation assessments</td>
<td>4.36</td>
<td>2.11</td>
<td>0.04*</td>
</tr>
<tr>
<td>RR4</td>
<td>Sanctions for owners not non-retrofitted EPBs</td>
<td>1.88</td>
<td>1.02</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Risk Information Dissemination and Communication strategies (RIDC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIDC1</td>
<td>Building Earthquake risk notice received from TA</td>
<td>2.03</td>
<td>2.51</td>
<td>0.61</td>
</tr>
<tr>
<td>RIDC2</td>
<td>Using social media to disseminate risk information</td>
<td>4.24</td>
<td>3.41</td>
<td>0.00*</td>
</tr>
<tr>
<td>RIDC3</td>
<td>Intensify the use of mass media</td>
<td>3.58</td>
<td>2.09</td>
<td>0.04*</td>
</tr>
<tr>
<td>Code</td>
<td>Information Provision and Communication Strategies</td>
<td>Mean</td>
<td>t-value</td>
<td>p-value</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td>------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>RIDC4</td>
<td>Reiterating of past earthquake stories and coping strategies</td>
<td>4.01</td>
<td>3.15</td>
<td>0.00*</td>
</tr>
<tr>
<td>RIDC5</td>
<td>Introduction of public recognition award</td>
<td>3.79</td>
<td>2.74</td>
<td>0.01*</td>
</tr>
</tbody>
</table>

**Risk Communication Management**

<table>
<thead>
<tr>
<th>Code</th>
<th>Form of communication</th>
<th>Mean</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC1</td>
<td></td>
<td>2.88</td>
<td>2.23</td>
<td>0.10</td>
</tr>
<tr>
<td>RC2</td>
<td>Frequency of communication</td>
<td>2.39</td>
<td>6.55</td>
<td>0.06</td>
</tr>
<tr>
<td>RC3</td>
<td>Quality of communication among stakeholders</td>
<td>4.79</td>
<td>2.74</td>
<td>0.01*</td>
</tr>
<tr>
<td>RC4</td>
<td>Quality of communication system</td>
<td>3.61</td>
<td>4.28</td>
<td>0.00*</td>
</tr>
<tr>
<td>RC5</td>
<td>Working relationship with owner</td>
<td>4.89</td>
<td>3.55</td>
<td>0.00*</td>
</tr>
<tr>
<td>RC6</td>
<td>Extent of managing public image and public relations</td>
<td>3.79</td>
<td>2.74</td>
<td>0.01*</td>
</tr>
</tbody>
</table>

*Significant information provision and communication strategies at 0.05 sig. level

### 5.1 Source of Earthquake Risk Information

Source of earthquake risk information could significantly influence property owners’ decision to adopt appropriate risk mitigation measures. The results presented in Table 3 show four significant sources of earthquake information that would likely influence how property owners make risk mitigation decisions regarding their EPBs. These significant information sources are government officials (SRI3), family/friends, (SRI4), mass media (SRI5) and lessons learnt from past earthquake experience (SRI6). Earthquake risk information provided by government officials, media, family/friends and from lessons learn from past earthquake experience are perceived as accurate and would likely enhance building owners’ decision to adopt appropriate risk mitigation measures. This finding shows that respondents assigned a higher level of credibility to these information sources implying a higher level of trust to these information sources. However, it can be plausibly concluded that a lower level of credibility and trust is assigned to risk information provided by earthquake risk professionals such as engineers, which could negatively influence seismic mitigation decisions. This low level of credibility may be related to building failures in the Christchurch earthquake disaster where newer buildings supposedly designed to new seismic standards were significantly damaged. According to Lindell and Perry (2004), when low credibility is accorded to hazard related professionals, people tend to search for other sources of risk mitigation information such as the media and family/friends. Thus, justifying the significance of the positive mean rating accorded to the media and family/friends in this study. Furthermore, the results show that the respondents accepted information gained through past earthquake experience without questioning, but does not intend to use any of this information in near future. The acceptance of information gained from past experience and coping strategies implied that human cognitive and decision-making processes relies more on association and familiarity with earthquake risk issues. This finding emphasise that personal experience produces more vivid memories and testable facts of the disaster event than a pallid description of events or mitigation approaches.
5.2 Quality of Earthquake Risk Information Provided

Analysis of the quantitative data presented in Table 3 provides ample evidence on the relative impact of good quality of risk information on mitigation decisions. Three main factors necessary to maintain a high level of quality earthquake risk information are; providing sufficient information about exposure to earthquake risks and the efficacy of mitigation measures (QIP1); providing information about benefits of retrofitting EPBs (QIP2); and the provision of a unified earthquake safety assessment information system (QIP4). The provision of sufficient information about a hazard and potential mitigation measures increases a person’s knowledge about the hazard, influence the level of risk perception and could consequently influence the adoption of adequate mitigation measures. In addition, the results indicate that the when potential benefits are adequately communicated, it may lead to a higher level of perceived benefits ascribed to an expected decision outcome, consequently, leading to higher chances of adopting risk mitigation decision. Therefore, property owners risk mitigation decisions can be promoted by highlighting potential benefits from adopting mitigation measures such increased safety, property value and possible future savings in a future earthquake event. This finding assert several postulations of expectancy-valence models that emphasised the role of perceived benefits in decision-making (Steel and Konig, 2006). Moreover, the findings from the study suggest a lack of provision for a unified earthquake risk information system, where all the stakeholders intending to use the information can access it. The availability of information system would provide quick access to earthquake risk information to property owners and all the stakeholders.

5.3 Regulatory Requirements

Two key potential regulatory requirements emerged in this study with the possibility to effectively facilitate property owners' decision to adopt adequate mitigation measures. These requirements are mandatory disclosure of building seismic risks (RR2) and comprisal of seismic risks in property valuation assessments (RR3) (see Table 3). Mandatory disclosure of seismic risks and comprisal of seismic risks in property valuation assessments through relevant policies would ensure that owners and property retailers are obligated to disclose a building’s seismic risk to prospective buyers or tenants at the point of sale or letting in the property market. The increased awareness may lead to informed market stakeholders and consequent improvement of the EPBs market value assessments. Thus, an increase in the property value would provide financial returns at the point of sale or letting to the owners of retrofitted EPBs, leading to the augmentation of their perceived benefits from implementing seismic mitigation measures as discussed in Section 5.2. It is not surprising that the implementation of a building grading system and sanctions for owners of non-retrofitted EPBs as shown by the results is insignificant. The purpose of such a grading system is to “raise awareness of seismic risk issues and ultimately induce voluntary adoption of beyond-code seismic performance standard imposed by the legislation. The grading system involves displaying a letter grade such as A to E on an EPB to denote the level of earthquake risk in the building. Some of the interviewees during the preliminary interview mentioned that the implementation of such a grading system is likely to result in a series of judicial cases where the grading and sanctions will be disputed.
5.4 Risk Information Dissemination and Communication Strategies

Findings from this study show that existing earthquake risk communication strategy has mainly by formal issuance of notice letters by the TAs to property owners and the distribution of brochures, which have been ineffective enhancing owners’ decisions to retrofitting their EPBs. To successfully disseminate and communicate earthquake risk information, the findings reveal four novel approaches using social networks such as twitter and face book (RIDC2), mass media (RIDC3), reiterating past earthquake experiences and coping strategies in social functions (RIDC4) and public recognition of pro-social mitigation behaviour (RIDC5). This research finding demonstrated that these novel four approaches can be used to increase the salience of seismic risk by providing accurate information to the public regarding the extent of risk exposure and severity of a potential disaster. These approaches would also help to shape people’s perception of risk and personalisation, disaster severity and improve their knowledge regarding the efficacy of risk mitigation measures. In addition, sufficient and appropriate media attention oriented towards effective mitigation measures rather than sensationalism is necessary to provide a favourable atmosphere for adopting earthquake mitigation measures.

5.5 Risk Communication Management

Results presented in Table 3 shows six significant communication management practices that could potentially increase the likelihood of building owners adoption of risk mitigation measures. Presently, only a formal written communication method such as letter and email represent the predominant means of communication. An exploration of regular face-face meeting (RC1 and RC2) may lead to joint ability among the stakeholders to collectively identify risks, proffer mitigation strategies and plan implementation actions necessary to adequately mitigate the risks. Other risk communication management strategies include high quality of communication among stakeholders in terms of communications planning and process monitoring (RC3), exploring quick dissemination of information and novel approaches (RC4) discussed in Section 5.4, and the establishment of appropriate method to generate, collect, disseminate, storage EPB risk information (RC5 and RC6). Effective earthquake risk communication process management would reduce some of the anomalies, such as lack of access to building risk information and poor risk communication process associated with the building safety evaluation process after the September 2010 earthquake in New Zealand. These anomalies contributed to the increased disaster losses in the February 2011 earthquake. Also, it is important for professionals such as engineers and government officials to strive and maintain a good public image and public relations with building owners by paying greater attention to seismic designs recommended approved by regulatory authorities. Having good public relations is particularly important in order to earn building owners’ trust regarding the efficacy of earthquake risk-reduction measures.

6. Discussion of Results

Significant earthquake risk information and communication strategies for improving seismic retrofit implementation in New Zealand have been revealed in this study. Effective risk information and communication strategies are needed to explain to those at risk regarding
how seismic hazard and risks are identified, assessed and managed effectively within limited resources. The research findings show that improving the quality of earthquake risk information provided to building owners, effective risk communication management, using regulatory requirements such as mandatory disclosure of seismic risks and most importantly the provision of a unified safety assessment information system would significantly improve the likelihood of property owners’ adoption of earthquake mitigation measures. These findings support PADM’s postulation regarding the use of a momentous risk-communication approach for improving earthquake risk mitigation.

The provision of a unified safety assessment information system that offers risk information about the vulnerability of potential EPBs to earthquake mitigation stakeholders and the public is central to bridging some of the related problems associated with seismic risk mitigation decisions. The information system would help other relevant professional groups and property market stakeholders to access any building’s seismic risk data and enable all stakeholders to work toward a consensus mitigation strategy. This availability of this information system will help them become aware of commonly encountered issues and imperatives regarding earthquake risks. Evidence from the recent Christchurch earthquakes provides further justification regarding the impact of haphazard information system on the overall earthquake vulnerability in New Zealand. Lack of access to adequate risk information about the performance of buildings in the earthquakes could significantly slow down the reconstruction process in Christchurch. In the CERA report (Canterbury Earthquakes Royal Commission (CERC), 2012). The provision of a safety information system could yield widely accessible and valuable information about the condition of potential EPBs across the country.

7. Conclusion

The objective of this study is to examine the relevance of mitigation information provided, and the effectiveness of existing and emerging communication strategies necessary to facilitate informed risk mitigation decisions. A survey research method adopted revealed seventeen significant strategies for improving seismic retrofit implementation of EPBs. These strategies are categorised in the following five groups; (i) source of information, (ii) quality of information provided (iii) regulatory requirements, (iv) information dissemination and communication strategies, and (v) risk communication process management. The research findings may help stakeholders involved in earthquake hazard and risk management to be better prepared towards the provision relevant information and communication strategies aimed at increasing the likelihood of EPBs owners’ adoption of risk mitigation measures. A better understanding of relevant earthquake mitigation information and communication strategies may help the stakeholders to review the existing approaches and could facilitate appropriate channelling of limited resources into the right areas to achieve desired risk mitigation decision.
References


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Seismic safety of places of worship in Italy’s Gran Sasso and Monti della Laga National Park

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Abstract title

The abundance of historic architectural heritage within Italy and its vulnerability to earthquake heighten the need for a risk analysis aimed at preserving buildings and their contents. In particular, churches are often more vulnerable than other buildings, even in the case of brief tremors. The reasons for this increased vulnerability are due to structure and peculiar geometrical proportions: presence of large open areas without internal walls to provide bracing, absence of intermediate ceilings, thinness of walls and certain vaulted structures, presence of thrust-exerting elements (arches, vaults). These features of churches, along with the use of architectural and structural criteria that are recognisable and comparable, albeit within the unique nature of each object, has led to a quest for specific procedures to assess seismic vulnerability, these being different to those utilised for ordinary buildings. The method involves dividing the building into macroelements, i.e. architectural sections of recognisable construction technique and showing similar seismic response (facade, apse, bell tower, etc.). The way in which damage can occur and the collapse mechanisms that the earthquake can provoke are therefore identified for each macroelement.

A specific risk analysis of places of worship has been carried out as part of the European project RECES modiquuss “The network of small old town centres as a model of urban quality and sustainable development” - INTERREG IIIA Adriatic cross-border programme. Research has been concentrated on places of worship located in an area comprising six communes of the L’Aquila province in central Italy. Many of the churches involved underwent a vulnerability analysis. The earthquake that struck central Italy on 6th April 2009 seriously damaged many of the churches surveyed prior to this event. It is now possible to compare the damage suffered and the mechanisms unleashed with the mechanisms predicted during survey and analysis.

Keywords: seismic vulnerability, churches, collapse mechanisms, damage, macroelements.
1. Introduction

The abundance of historic architectural heritage within Italy and its seismic vulnerability, i.e. its susceptibility to damage or alteration following an earthquake, heighten the need for a risk analysis of certain areas aimed at preserving buildings and their contents. A specific risk analysis of places of worship was carried out by the L'Aquila branch of the National Research Council Construction Technology Institute (NRC CTI) as part of a European project whose objectives included knowledge, protection and enhancement of cultural heritage, including in support of socioeconomic development linked to sustainable tourism. Research concerned places of worship located in an area comprising six communes of the L'Aquila province: Barisciano, Calascio, Castelvecchio Calvisio, Castel del Monte, Carapelle Calvisio, S. Stefano di Sessanio. This area forms one of the Cultural Tourism Districts of the Gran Sasso and Monti della Laga National Park called Terre della Baronia. This survey of places of worship has led to the identification and registration of 64 elements, some in a state of ruin, comprising churches, convents and chapels (figure 1).

![San Cipriano Church in Castelvecchio Calvisio](image)

Figure 1. San Cipriano Church in Castelvecchio Calvisio

Some of the churches involved, representing the largest part of the sample, underwent a vulnerability analysis. The sample consists of 33 mainly aisleless churches of various size and complexity. The method used is about the study of building and the analysis of seismic risk with a quickly form and an analytical method, according to the indications of the Italian rule for cultural heritage.

The earthquake that struck central Italy on 6th April 2009, in particular the city of L'Aquila and the above-mentioned communes, has enabled a check to be carried out on the effectiveness of the forecasts made and methodology used.
2. SAMPLE TYPE ANALYSIS

The different types of construction were identified, these ranging from a simple chapel to very large churches (see table 1 and figure 2). The higher the surface area, the greater the building’s structural complexity. The sample surveyed comprises 73% aisleless churches and 24% with two naves or three aisles. 70% are buildings with vaulted structures. Domes are present in only 24% of the sample. Projections and gables are found in 64% of the sample and mainly feature bell gables and gable façades, whilst 21% have a bell tower. 36% of the sample have an apse and 12% a transept. Only 6% of the churches have a prothyron.

![Figure 2: Plan of the Santa Maria della Pietà di Collerotondo church, Santa Maria ab Extra church, both in Barisciano, and the San Marco Evangelista church in Castel del Monte](image)

Various types of façade are to be found (figure 3), the most characteristic and at the same time most vulnerable feature, but all meet standard architectural criteria. The rectangular façade typical of L’Aquila (45% of sample) is the most common, whilst 24% of the churches surveyed have a gabled façade and in 21% of cases it follows the outline of the roof. This last-mentioned type is a feature of aisled churches or those having side chapels. It is worth noting that 39% of the sample have a façade with gables and other projections that can be particularly vulnerable in the event of an earthquake.

![Figure 3: Façade of the churches of Santa Maria di Valleverde in Barisciano, Madonna del Lago in S. Stefano di Sessanio and Santa Maria and San Vittorino in Carapelle Calvisio](image)
3. SEISMIC VULNERABILITY ANALYSIS

An in-depth study was conducted into the construction of each of the churches, this considering the following aspects:
- its history, using available bibliography and archive material from the L'Aquila Heritage Commission;
- comprehensive geometric, technological and material characteristics survey based on direct observation and the survey and archive material available from the L'Aquila Heritage Commission (figure 4);
- survey of cracks and deformation.

![Figure 4. Santa Maria di Valleverde church in Barisciano, axonometric projection](image)

In addition, these churches also underwent a data sheet survey using the “Level II churches damage and vulnerability survey sheet”. The survey method is based on identifying 28 possible damage mechanisms affecting a series of the church’s macroelements and analysing the factors that can facilitate or prevent the activation of such mechanisms. The procedure leads to the creation of a vulnerability index \( i_v \) ranging from 0 to 1, using a suitable combination of points awarded to the various seismic vulnerability and protection elements. This index offers comparison of the degree of vulnerability of churches of different shapes and sizes, allowing a sort of hierarchy to be established (see fig. 5).

For each damage mechanism considered, its frequency of activation was calculated along with the damage level as a percentage of all the churches surveyed. The information provided by the data sheets highlights the absence of seismic damage. When present, damage is limited and does not exceed level 3. Indeed, the main problem was caused by lack of maintenance, as noted during surveying.
By assessing the damage mechanisms that can be activated in the presence of a certain macroelement, it can be noted that façade mechanisms are likely in almost all the churches (97%). This shows that the sample is composed of buildings that are either isolated or form part of complexes in which such macroelement can be identified. The highest damage level, and thus mechanism activation, is also found: 24% overturning of façade, 15% top, 27% in-plane mechanisms. The cases noted of overturning are characterised by the presence of vertical cracks on the side walls close to the façade, mainly due to poor bonding between masonry walls. Cracks relating to a mechanism at the top of the façade is almost always due to the fact that façades project above the top of the roof and are pounded or the thrust of nave vaults. On the other hand, in-plane mechanisms are helped by the presence of various openings in the façade, some of notable size. The greater possibility of activating a
transverse response (100%) as opposed to mechanisms connected to nave vaults (70%) underlines the absence of vaulted structures in some churches that instead have timber trusses or beams resting on stone cross arches. In this case, the damage is to be found above all in the vaults (mechanism activated in 21% of cases) with cracks in the keystone or on the lunettes, mainly due to the absence of suitable protection to dampen thrust. The mechanism in the roofing is also likely to be activated in almost all the buildings analysed (97%). Some of the roofing structures are constructed using timber trusses, but most are made using reinforced concrete. In 88% of the sample, interaction is possible between the individual structures forming the building as a whole.

4. MASONRY QUALITY ANALYSIS

Masonry quality was assessed by referring to the “Level I data sheet for assessing masonry type and quality”. Using the data contained in the survey sheets for the sample considered it has been possible to carry out a statistical survey with regard to the presence of the different construction parameters that can be found in the various types of masonry. A total of 67 masonry structures have been identified and these can be broken down into four types specified by current technical standards (figure 6). The data sheets serve the dual purpose of facilitating the collection and filing of information and allowing immediate identification of the masonry’s specific characteristics and determination of the main types. By analysing the data concerning their constituents, it can be seen that the masonry structures are all composed of elements of a calcareous nature with lime mortar.

<table>
<thead>
<tr>
<th>Tipologia muraria</th>
<th>Numero casi</th>
<th>Percentuale</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Muratura in pietrame disordinata</td>
<td>53</td>
<td>79%</td>
</tr>
<tr>
<td>B. Muratura a conci sbozzati</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>C. Muratura in pietra a spacco con buona tessitura</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>E. Muratura a blocchi lapidei squadrati</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>Totale</td>
<td>67</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Table 2. Masonry types*

The breakdown of the different types (table 2) shows that most of the sample belongs to type A, whilst there are no examples of type D. Type E often regards the façade, this being built with large blocks of limestone that are carefully squared in order to produce a building of striking architectural impact.
Thermal imaging was carried out on some of the buildings in order to assess, without touching plastered surfaces, the elements required for characterization of structural members such as: the vertical arrangement of the masonry structure, presence of gaps/irregularities and substructures, vault type, degree of instability and details of the cracks. Thermal imaging was carried out by a workgroup led by Prof. Ermanno Grinzato. The thermal images produced enabled direct verification of the quality of the information that can be obtained (figures 7, 8).
5. ANALYTICAL VULNERABILITY ASSESSMENT

5.1 LV1 assessment level

The analytical vulnerability assessment of the churches in question was carried out in accordance with the procedure specified in the “Guidelines for the assessment and reduction of the seismic risk to cultural heritage”. Initially, the simplified LV1 model proposed by the above-mentioned guidelines was applied. This model, based on statistical data collected from previous Italian earthquakes, enables an estimate to be made of the peak ground acceleration corresponding to the Ultimate Limit State (ULS) and Damage Limitation State (DLS) as a function of the vulnerability index $i_v$ calculated with the damage and vulnerability survey sheet using the following expressions:

\[
a_{SLD}^{ULS} = 0.025 \times 1.8^{2.75 - 3.44i_v}
\]

\[
a_{SLD}^{DLS} = 0.025 \times 1.8^{5.1 - 3.44i_v}
\]

The structure’s safety index at the Ultimate Limit State represents the ratio of structural capacity to seismic demand and can be calculated as:

\[
I_s = \frac{a_{SLD}}{\gamma_i S a_g}
\]

where: $a_{ULS}$ is the ground acceleration that will lead to the ultimate limit state being reached; $S$ is a parameter that takes account of the stratigraphic profile of the underlying subsoil and morphological effects; $\gamma_i$ is the importance coefficient that takes account of the building’s position and its cultural importance. $a_g$ is the reference acceleration for the site. This is the same for the Damage Limitation State. This purely statistical approach may be considered correct since it refers to the analysis of a specific area. It allows drawing up of lists of priority and programming of more detailed assessments in the best possible manner with a view to implementing preventive measures. Indeed, the use of a single model for assessments of this type allows more objective comparison as far as seismic risk is concerned. Reference accelerations for the communes in which the places of worship are located were taken from current technical standards. Safety indices at ULS and DLS for the churches in question are given in the following table and graphs (table 3, figure 9).

As confirmation of that previously noted in the case of minor earthquakes, it is worth pointing out that these structures are more susceptible to DLS than ULS. It may be noted that ground acceleration values corresponding to the ultimate limit state (ULS) are fairly high. Indeed, mechanisms will generally be activated at lower values, although higher acceleration levels are needed before causing the structure to collapse.

In order to make a more accurate forecast as to the seismic risk for these buildings, more in-depth studies and processing are required, applying the LV2 second level procedure based on the analysis of individual mechanisms.
<table>
<thead>
<tr>
<th>N.</th>
<th>Chiesa</th>
<th>Comune</th>
<th>$S$</th>
<th>$p$</th>
<th>$F_s$</th>
<th>$g_{ULS}$</th>
<th>$g_{DLS}$</th>
<th>Livello di sicurezza alle ULS</th>
<th>Livello di sicurezza alle DLS</th>
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<tr>
<td>1</td>
<td>S. Cipriano</td>
<td>Castelvecchio</td>
<td>1.25</td>
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<td>1.12</td>
<td>0.05</td>
<td>0.21</td>
<td>0.063</td>
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<td>S. Rosco</td>
<td>Castel del Monte</td>
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<td>0.04</td>
<td>0.17</td>
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<td>S. Stefano di Sessanio</td>
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<td>0.15</td>
<td>0.49</td>
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<tr>
<td>10</td>
<td>Immacolata Concezione e Cappella</td>
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<td>1.12</td>
<td>0.04</td>
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<td>0.49</td>
<td>0.78</td>
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<tr>
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<td>S. Pasquale</td>
<td>Carapelle Calvisio</td>
<td>1.25</td>
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<td>0.16</td>
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<td>0.47</td>
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<tr>
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<td>Castel del Monte</td>
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<td>0.65</td>
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<td>0.15</td>
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<tr>
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<td>0.65</td>
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<td>0.49</td>
<td>0.79</td>
</tr>
<tr>
<td>17</td>
<td>S. Leonardo</td>
<td>Calascio</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.04</td>
<td>0.15</td>
<td>0.44</td>
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<td>0.65</td>
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<td>0.15</td>
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<td>Castelvecchio</td>
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<td>1.12</td>
<td>0.04</td>
<td>0.17</td>
<td>0.41</td>
<td>0.65</td>
</tr>
<tr>
<td>22</td>
<td>Madonna del Rosario</td>
<td>Bartisciano</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.03</td>
<td>0.14</td>
<td>0.41</td>
<td>0.65</td>
</tr>
<tr>
<td>23</td>
<td>S. Vittorino</td>
<td>Carapelle Calvisio</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.03</td>
<td>0.13</td>
<td>0.40</td>
<td>0.64</td>
</tr>
<tr>
<td>24</td>
<td>S. Maria della Pietà</td>
<td>Bartisciano</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.03</td>
<td>0.13</td>
<td>0.40</td>
<td>0.64</td>
</tr>
<tr>
<td>25</td>
<td>Anche Same e del Suffragio</td>
<td>S. Stefano di Sessanio</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.04</td>
<td>0.16</td>
<td>0.40</td>
<td>0.62</td>
</tr>
<tr>
<td>26</td>
<td>Oratorio Confraternita del SS Rosario</td>
<td>Bartisciano</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.03</td>
<td>0.12</td>
<td>0.37</td>
<td>0.58</td>
</tr>
<tr>
<td>27</td>
<td>S. Martino</td>
<td>Bartisciano</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.04</td>
<td>0.14</td>
<td>0.35</td>
<td>0.56</td>
</tr>
<tr>
<td>28</td>
<td>S. Nicola di Bari</td>
<td>Calascio</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.04</td>
<td>0.14</td>
<td>0.35</td>
<td>0.55</td>
</tr>
<tr>
<td>29</td>
<td>S. Marco Evangelista</td>
<td>Castel del Monte</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.03</td>
<td>0.13</td>
<td>0.35</td>
<td>0.55</td>
</tr>
<tr>
<td>30</td>
<td>S. Maria in Ruvo</td>
<td>S. Stefano di Sessanio</td>
<td>1.25</td>
<td>0.65</td>
<td>1.12</td>
<td>0.03</td>
<td>0.11</td>
<td>0.35</td>
<td>0.55</td>
</tr>
<tr>
<td>31</td>
<td>Madonna del Lago</td>
<td>S. Stefano di Sessanio</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.03</td>
<td>0.13</td>
<td>0.32</td>
<td>0.51</td>
</tr>
<tr>
<td>32</td>
<td>S. Maria e S. Vittorino</td>
<td>Carapelle Calvisio</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.03</td>
<td>0.13</td>
<td>0.37</td>
<td>0.51</td>
</tr>
<tr>
<td>33</td>
<td>S. Flaviano</td>
<td>Bartisciano</td>
<td>1.25</td>
<td>0.80</td>
<td>1.12</td>
<td>0.03</td>
<td>0.12</td>
<td>0.28</td>
<td>0.45</td>
</tr>
</tbody>
</table>

*Table 3. Safety indices*

*Figure 9. Safety indices at ULS and DLS*
5.2 Linear kinematic analysis

As regards places of worship, the guidelines prefer kinematic analysis methods (linear and non-linear) applied to the various macroelements that thus become the reference structural units. This highlights the need to utilise local models and assessments rather than complex models.

As previously stated, during the course of the research project, besides collecting historical records regarding the churches in order to have a better idea of past events, comprehensive surveying was also carried out along with observation and cataloguing of the types of vulnerability present.

Observing a church’s alteration, disrepair and damage processes reveals the essential characteristics that condition its seismic vulnerability. The weakest parts of the structure are identified, those that could collapse when the earthquake strikes, thus indicating the ways in which the earthquake will be able to cause damage. This involves a preliminary qualitative analysis that is swiftly followed by a quantitative assessment of stability.

The aim of the qualitative analysis is to highlight the mechanisms whose presence and activity are revealed by some degree of damage for which they are directly responsible and identify the mechanisms most likely (figure 10) to be activated in the future based on observation of the churches’ structural features, type and vulnerability attributable to specific characteristics or else statistically common. Having ascertained the mechanisms already activated or likely to be so, linear kinematic analysis was carried out in accordance with technical standards.

![Figure 10. On the left the San Francesco church in Carapelle Calvisio (AQ), façade overturning mechanism; on the right the Madonna del Lago church in S. Stefano di Sessanio, tympanum overturning mechanism with formation of oblique hinges.](image)

6. CONCLUSION

As previously stated, the seismic vulnerability study of the sample described was carried out over the two-year period 2007-2008.
The earthquake on 6th April 2009 struck all communes in the Baronia di Carapelle area to a lesser or greater degree. With the exception of Calascio, all communes fall within the "seismic footprint".

The churches studied have suffered varying amounts of damage, in some cases severe (figure 11).

*Figure 11. Example of damage suffered by the churches: starting from top left the churches of Santa Maria e San Vittorino (Carapelle Calvisio), San Marco Evangelista (Castel del Monte), Madonna del Rosario and Santa Maria del Carmine (Barisciano)*

Damage assessment was carried out using the church seismic damage survey sheet that considers the same macroelements and damage mechanisms as the vulnerability survey sheet. The method associated with the survey sheet provides for the calculation of a damage index $i_d$ (ranging from 0 to 1) representing the church’s average damage level (fig. 12).

*Figure 12. Damage indices for the sample of churches*
It can indeed be noted that there is good correspondence between mechanisms deemed more hazardous (see table 8) and those in which the highest damage level was found.

<table>
<thead>
<tr>
<th>DAMAGE MECHANISMS</th>
<th>D0(%)</th>
<th>D1(%)</th>
<th>D2(%)</th>
<th>D3(%)</th>
<th>D4(%)</th>
<th>D5(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. overturning of facade</td>
<td>97%</td>
<td>79%</td>
<td>12%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>2. Mechanism at the top of the facade</td>
<td>97%</td>
<td>88%</td>
<td>9%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>3. facade in-plane mechanisms</td>
<td>97%</td>
<td>79%</td>
<td>13%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>4. Pygmy or wavelock</td>
<td>6%</td>
<td>94%</td>
<td>0%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>5. New anomalous response</td>
<td>110%</td>
<td>79%</td>
<td>3%</td>
<td>12%</td>
<td>12%</td>
<td>0%</td>
</tr>
<tr>
<td>6. shear mechanism in the wall</td>
<td>100%</td>
<td>88%</td>
<td>9%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>7. Colonnade longitudinal response in aisled churches</td>
<td>21%</td>
<td>97%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>8. nave vaults</td>
<td>70%</td>
<td>82%</td>
<td>9%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>9. aisle vaults</td>
<td>110%</td>
<td>94%</td>
<td>0%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>10. overturning of transverse end walls</td>
<td>12%</td>
<td>24%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>11. shear mechanism in transverse walls</td>
<td>12%</td>
<td>27%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>12. transverse vault</td>
<td>12%</td>
<td>24%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>13. triumphal arch</td>
<td>36%</td>
<td>79%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>14. dome</td>
<td>21%</td>
<td>83%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>15. rostrum</td>
<td>9%</td>
<td>83%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>16. overturning of apse</td>
<td>56%</td>
<td>79%</td>
<td>3%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>17. shear mechanism in presbytery or apse</td>
<td>73%</td>
<td>91%</td>
<td>0%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>18. presbytery or apse vaults</td>
<td>64%</td>
<td>83%</td>
<td>6%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>19. Mechanism in roofing (side wall)</td>
<td>97%</td>
<td>88%</td>
<td>9%</td>
<td>6%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>20. Mechanism in roofing (transparens)</td>
<td>9%</td>
<td>97%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>21. Mechanism in roofing (apse and presbytery)</td>
<td>73%</td>
<td>83%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>22. overturning of chancel</td>
<td>36%</td>
<td>83%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>23. shear mechanism in chancel walls</td>
<td>42%</td>
<td>88%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>24. chancel vaults</td>
<td>42%</td>
<td>83%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>25. interaction at plan and elevation irregularities</td>
<td>88%</td>
<td>91%</td>
<td>3%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>26. proportions (bell gable, apse, presbytery, transept)</td>
<td>44%</td>
<td>94%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>27. bell tower</td>
<td>24%</td>
<td>94%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>28. bell gable</td>
<td>30%</td>
<td>94%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 4. Damage mechanisms and damage percentage

The earthquake of 6 April 2009 has allowed us to verify the validity of scientific method used for the risk analysis of the churches in the "restricted area". The next phase of research will be directed toward a consolidation of the procedures in order to allow vulnerability assessments of the churches on a large site. The processed data can be used to study risk analysis. More over they can be useful to the building owners as a guide to restore the cultural heritage.

References


Should the Disaster Management Strategies in Bangladesh be just about Constructing New Shelters?

Muhammad Nateque Mahmood¹, Subas Dhakal², MD Kamruzzaman³

Abstract

With a population of over 143 million people and a population density of more than 1,200 persons per km² Bangladesh is a very densely populated country. The country’s geographic location in the waters of Bay of Bengal, often the source of tropical cyclones and storm surges, makes Bangladesh one of the most natural disasters prone nations in the world. A severe tropical cyclone hits the country, every 3 years on average. As 16 major cyclones have hit the country since 1960 with the loss of nearly 500,000 lives, multi-purpose cyclone shelters – that can provide refuge to susceptible population in the events of natural hazards and to a certain extent with the utility of community functionalities during normal times – have become a vital component of disaster management strategies. Country has already constructed more than 2,500 such shelters across 16 of the most disaster prone coastal districts. This paper uses content analysis of disaster management policies, and programs in order to comprehend and assess the distributions of shelters with a lens of integrated strategic asset management framework. Analysis of secondary data indicates that existing cyclone shelters are not equitably distributed to cater the needs of the highly vulnerable population. In the backdrop of the recommendation of The World Bank [TWB] that the country needs 5,500 new shelters (TWB, 2010), this paper contends that future construction of cyclone shelters must be need as well as evidence-based in order to ensure that highly vulnerable population benefits from cyclone shelters the most.

Keywords: Cyclone Shelters, Disaster Management, Evidence-based Strategy, Leximancer, and Integrated Strategic Asset Management

1. Introduction

With a population of over 143 million people and a population density of more than 1,200 persons per square kilometre, Bangladesh is a densely populated country in the South Asia Subcontinent (BBS, 2012). Bangladesh is also the world’s third most vulnerable country to

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sea-level rise in terms of the number of people, and among the top ten countries in terms of percentage of people living in low-lying coastal zones (Pender, 2008). Sixteen coastal districts along the Bay of Bengal are prone to severe tropical cyclones with sustained winds of 64 knots (74 miles/hour) or more that often generate storm surges and huge waves. These surges can rise as high as seven metres and the flood waves can travel up to 30 miles inland. On average, a severe tropical cyclone hits Bangladesh every 3 years and the country has been hit by 16 major cyclones with a loss of nearly 500,000 lives since the 1960s (Karim and Mimura, 2008). It is apparent that the need to reduce natural disasters casualties, particularly cyclone-related deaths, is nowhere more crucial than in Bangladesh.

The country has built more than 2,500 multipurpose cyclone shelters across 16 of the most cyclone-prone coastal districts (CEGIS, 2009). These shelters – that can provide refuge to susceptible population and to a certain extent with the utility of community functionalities during normal times – have become an integral component of country’s disaster management strategy. Since the changing climate and associated sea-level rise is predicted to further increase the frequency and intensity of cyclonic events in the foreseeable future (Karim and Mimura, 2008), The World Bank (2010) estimates that Bangladesh needs more than fifty five hundred new cyclone shelters in order to protect the vulnerable population from natural disasters. While the actual number of the need is contested, the current understandings of the way cyclone shelters are distributed and managed are inadequate. It is in this context, this paper makes explores the utility of an integrated strategic asset management (ISAM) framework (AAMCoG, 2012), developed in conjunction with asset management industry associations in Australia, in order to examine the state of cyclone shelters in Bangladesh.

The paper begins with an introductory overview of ISAM framework and its relation to the construction and management of cyclone shelters as assets. An empirical study examining the state of cyclone shelters in 16 coastal districts of Bangladesh is presented next, including the method as well as the results and discussion. The paper ends with the recommendation that future construction of cyclone shelters must be need as well as evidence based so that it can serve the purpose of benefiting highly vulnerable population.

2. ISAM Framework and MPCS Management

According to the BSI (2008), asset management can be defined as ‘systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan’ (p. 2). In line with this definition and also to provide a contemporary outline to assist asset service owners, providers and operators, AAMCoG (2011) has developed an ISAM framework (Figure 1). The elements of the ISAM framework are put together in order to guide achieving optimisation of service delivery of engineering and infrastructure assets.

The ISAM framework (AAMCoG, 2011) is based on the following five principles:
i. Assets exist to support service delivery. Therefore non-asset solutions should be considered

ii. Agencies should manage assets consistent with whole-of-government policy frameworks and take into account whole of life costing, future service demands and balance between capital expenditure and maintenance requirements

iii. Asset management should be integrated with agency strategic and corporate planning

iv. Asset management decisions should holistically consider sustainability outcomes: environmental, social, economic and governance

v. Governance arrangements should clearly establish responsibility for functional performance of, and accountability for, the asset and service delivery (pp. 5).

*Figure 1: Integrated strategic asset management framework (source: AAMCoG, 2011)*

These principles are particularly useful for shaping management of cyclone shelters in order to internalise the needs and expectations of community stakeholders regarding sustainable management. For the purpose of this paper, we focus on the external factors of the framework and utilise it in order to assess the following three factors: a) environmental, b)
community needs and expectations, and c) whole-of-government policy in relation to cyclone shelters distribution and management in Bangladesh. These three factors are elaborated upon next.

2.1 Environmental factors

Recognition of the environmental risks e.g. the changing climate is a valuable first step towards better planning of new infrastructure investments and mitigating potential damage to existing infrastructure (CSIRO, 2006). Like any other major infrastructure assets, cyclone shelters need to operate in dynamic circumstances where they are exposed to short, medium and long-term variability in ambient environmental conditions. The variability includes the estimation of environmental conditions e.g. river erosion, tsunami, earthquake that can be expected over the life of cyclone shelters. These environmental factors can influence the geographical locations of asset construction, their functionalities, and most importantly, their core purpose of delivering services to the vulnerable people. While statistical view of the variability of environmental conditions is understood to have an impact on the construction and management of assets, incorporation of environmental conditions into asset planning and design has been largely overlooked so far (Rayner, 2010). The capacity for identification, assessment and evaluation of risks associated with environmental factors on micro, meso and macro level needs to be substantially increased in managing assets like the cyclone shelters and the information also needs to be systematically integrated in the planning processes of constructing new and existing assets (Smit et al., 2006; Nelson et al., 2007).

2.2 Community needs and expectations

Community needs and expectations need to be managed through the effective institutionalisation of stakeholder engagement. Stakeholder engagement is the process of mapping and interpreting the expectations of external and internal groups and/or individuals, who have stakes in asset management activities or will be effected directly or indirectly by its outputs. According to the Beach and Keast (2010), stakeholder engagement comprises of stakeholder identification, stakeholder classification, strategy development, stakeholder engagement, and of the maintenance of relationships. From the asset management perspective, stakeholder engagement is essential throughout all stages of the asset life cycle. For instance, community is likely to play a major role by sharing local knowledge about environmental factors and actual needs which eventually assist in planning, designing, constructing, operating, maintaining and disposing phases of any infrastructure assets.

2.3 Whole-of-government policy model

Whole-of-government policy model, which is comprised of legislation, policies, plans, service delivery strategies and standards, capital and recurrent budgets, government institutions; and partnerships including with working groups, community based organisations and private providers. In case of public assets, the identification and analysis of the community’s need for services is regularly undertaken by different tiers of government agencies and communicated to various departments in a range of ways, including emerging policy,
legislation, priorities and objectives. These are translated by agencies into specific departmental objectives, performance indicators, services and service standards which are addressed in major documents such as strategic plans, budget documentation and annual reports. Bangladesh has a regulative framework for disaster management that provides guidance for relevant policy documents. The contents of three documents related to the regulative framework: a) the Disaster Management Act, b) the National Plan for Disaster Management, and c) the Standing Orders on Disaster (still in a draft stage) are analysed in the context of whole-of-government policy model under the ISAM framework adopted earlier.

3. Methodology

The central research question that this paper addresses is whether or not cyclone shelters in Bangladesh are distributed as per the actual needs. An exploratory case study approach (Blatter, 2008) which examines an operating environment of cyclone shelters using multiple sources of quantitative and qualitative data was selected as the principal research method for this study.

A case study approach is particularly useful in qualitatively understanding a phenomenon because the method is open to the use of theory or conceptual categories that guide data collection and data analysis (Yin, 1984; Meyer, 2001). We relied on various secondary data sources e.g. the Ministry of Food and Disaster Management (MFDM), and the Bangladesh Bureau of Statistics (BBS) in calculating the ratio between population vulnerable to cyclones and cyclone shelters. We also made use of an ISAM framework in order to explore three of the external factors that are important to consider prior to constructing shelters: a) environmental factors e.g. frequency of cyclones, b) community needs and expectations e.g. vulnerability of the people, and c) whole-of-government policy e.g. disaster related policies and their implementation. The utility of exploring these factors is such that it enables us to triangulate our analysis through the content analysis of disaster management policies, programs and literature on disaster management in assessing the distribution of cyclone shelters.

The contents of three policy documents:, i) The Disaster Management Act, ii) The National Plan for Disaster Management, and iii) The Standing Orders on Disaster were analysed using a Leximancer software. Leximancer differs from the standard content analysis, which identifies themes and concepts based on the word frequency and co-occurrence of families of terms (Smith & Humphreys 2006; Smith 2003). Leximancer was particularly useful for examining the interconnectedness of central themes contained within the documents outlined above.

4. Results and Discussions

4.1 Cyclone shelters

In order to reduce the cyclone-related casualties, Bangladesh has already built more than 2,583 cyclone shelters across 16 of the most cyclone-prone coastal districts. The analyses indicate that nearly one tenth (246) shelters are deemed unusable (CEGIS, 2009). As Figure
1 shows, Patuakhali district has the highest percentage of unusable cyclone shelters (30.38%) whereas Satkhira and Shariatpur districts have 100% of cyclone shelters usable. While some of the plausible causes behind the high frequency of shelters being unusable are discussed in the next section, they are worthy of further field investigation.

![Figure 2: The State of Cyclone Shelters in 16 Coastal Districts of Bangladesh](image)

The analyses also indicate that existing shelters are not equitably distributed to cater the needs of the highly vulnerable population. For instance, Noakhali district with a total of highly vulnerable population of 1,807,000 has an existing shelter capacity for accommodating only 266,000 people. That means at present 85% of the vulnerable population in the district are exposed to high risk. Conversely, Khulna district without any highly vulnerable population has an existing shelter capacity for accommodating 76,000 people. These findings clearly indicate that shelters are constructed on an ad hoc basis and hence inequitably distributed.

### 4.2 Environmental factors

Most of the cyclone shelters that are deemed unusable because of the lack of day-to-day maintenance and external factors such as river bank erosion, poor quality of construction materials, less consideration given to potential high wind speed at construction. It could also the case that, people displaced during the cyclones are hesitant to use these facilities because they are worried about the structural well-being of these shelters due to poor maintenance during normal times. Consequently, cyclone shelters are abandoned and become unusable when needed the most.
For instance, as Figure 3 indicates the structural assessment of 2,583 cyclone shelters conducted by CEGIS (2009) revealed that around 3% of shelters were vulnerable to tsunami, nearly 8% were vulnerable to cyclone and a whopping 73% were vulnerable to earthquake. If these shelters are to be the backbone of the overall disaster management strategy, the construction and management cyclone shelters need to take into hazards other than cyclones in consideration as well. Cyclone shelter construction decisions must rely on evidence-based decision-making and consider environmental factors over the entire life-cycle of proposed shelters and not just the construction phase. Unless these considerations inform the design, specification, construction materials selection and techniques, operating models and disposal procedures of the cyclone shelters, the overall utility of these assets are likely to be reduced in the event of cyclones or other natural disasters for that matter.

4.3 Community needs and expectation

Although there is no unanimous agreement over what constitutes a genuine community stakeholder, an individual or an organisation with a stake or an interest in various stages of cyclone shelters can be considered one. The needs and expectations of these community stakeholders are more or less represented through management committees that are often democratically governed by the local people at the grassroots. However, only 19% of shelters have community participation mechanism in place during the operation phase (CEGIS, 2009).
These findings suggest that disaster management strategy is more or less concentrated on constructing the shelters for the sake of it instead of long-term utility of the shelters. As Figure 4 suggests, the majority of cyclone shelters do not have community based participatory governance mechanism in place. In particular, Shariatpur district performs very poorly in this regard with none of the shelters having participatory governance mechanisms.

### 4.4 Whole-of-government framework

Of the three policy documents identified earlier, The Disaster Management Act forms the legal basis (i) for the protection of life and property (ii) to manage long term risks from the effects of natural as well as technological and human induced hazards, and (iii) to respond to and recover from a disaster. The National Plan for Disaster Management provides the overall guideline for the relevant sectors and the disaster management committees at all levels to prepare and implement specific plans for their respective areas. The plan also identifies the key sectoral policy agenda for disaster management. The Standing Orders on Disaster provide a detailed institutional framework for disaster risk reduction and emergency management. These orders are expected to outline detailed roles and responsibilities of Ministries, divisions, departments, various committees at different levels, and other organizations involved in disaster risk reduction and emergency management.
As Figure 5 shows, the draft Disaster Management Act and the National plan for Disaster Management are relatively close together when compared to the Standing Order on Disasters in Bangladesh, indicating more overlap in terms of the contents analyses. Based on the Leximancer analyses, five of the most prominent concepts in the three documents are concisely included in Table 1 below. The table clearly shows that the concept of community shows high connectivity between the Act and the Plan. However, the notion of community is disconnected from where it is needed the most, from the Standing Order.

Table 1: Five prominent concepts identified by Leximancer

<table>
<thead>
<tr>
<th>Policy Document</th>
<th>Prominent Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaster Management Act</td>
<td>Committee, services, hazards, community and climate change</td>
</tr>
<tr>
<td>National Plan for Disaster Management</td>
<td>Climate change, hazards, community, emergency and information</td>
</tr>
<tr>
<td>Standing Order Disasters in Bangladesh</td>
<td>Materials, local, rescue, rehabilitation and food</td>
</tr>
</tbody>
</table>

In order to comprehend community needs and expectations in the construction of cyclone shelters, it is important to involve local people including vulnerable groups for improved management of the shelters. However, the Standing Order as it is seems to have failed in serving as guidance to community based cyclone shelters management.
5. Conclusion

This paper began with an introductory overview of ISAM framework and utilised this framework in order to explore the construction and distribution of cyclone shelters in Bangladesh. The results indicated three main findings. First, there was a lopsided focus on constructing the shelters for the sake of it, rather than ensuring ways to manage these assets by engaging communities. For instance, nearly 9% of the existing shelters were deemed unusable in the event of natural disasters. In some cases e.g. Patuakhali upto one-third of the cyclone shelters were unusable. Second, the current distribution of cyclone shelters was disconnected from the on-ground needs. The cyclone shelters were not equitably distributed to cater the needs of the highly vulnerable population e.g. 85% of the vulnerable people in Noakhali district are at risk in the event of future natural disasters. Third, while the actual construction of the shelters was the responsibility of several layers of government agencies, these agencies did not have clear guidelines for the management of the cyclone shelters. The fact that less than one-fifth of the shelters have community participation mechanism in place during the operation phase means that the existing planning mechanism is myopic and has failed to take into account the operation phase and beyond.

Based on these findings, the paper sees some value in the ISAM framework as an integrated guidance for need-based construction and evidence-based management of cyclone shelters. In order to achieve this, hazard and risk maps and related information need to be not only updated regularly but also used in planning processes at all levels for cyclone shelter construction and management. There is no doubt that existing and new shelters are vital for mitigating or minimising the casualties of vulnerable populations in the event of natural disasters. If cyclone shelters are to be the backbone of disaster management strategies in Bangladesh, these facilities cannot be disconnected from the very local communities that they service. This paper recommends that policy level direction on the distribution and management of cyclone shelters might be more effective when: a) it promotes democratic election the management committee at the bottom-up level rather top-down level, and b) incorporating community needs and requirements in designing the facilities and finalisation of proposed shelter locations.

Acknowledgement

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Social resilience in the context of South African cities: Exploring the interdependencies of urban and social resilience

Trudi Swanepoel¹; Chrisna du Plessis²

Abstract

Urban areas as socio-ecological systems can be seen as consisting of an urban environment created by biogeochemical processes (including those originating from human activities) and governed by natural laws and an interior noosphere created by and experienced through the human psyche and social interaction to give rise to social and cultural structures. These two spheres interact to create the dynamics of a city and therefore urban resilience needs to consider not just biophysical or social resilience, but also the interactions between them. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects. This paper explores the interdependencies between resilience in the social and biophysical systems of the South African city. From the scenarios based on real events in cities in South Africa we can see the relationships between the social and biophysical resilience of an urban environment.

Keywords: Resilience, interdependencies, urban resilience, social resilience

1. Introduction

The notion of urban areas as socio-ecological systems is becoming more widely accepted (Alberti et al. 2003; Moffat and Kohler, 2008; Du Plessis, 2009a). As such they can be seen as consisting of an urban environment created by biogeochemical processes (including those originating from human activities) and governed by natural laws, and an interior noosphere created by and experienced through the human psyche and social interaction that give rise to social and cultural structures (Haberl et al., 2004; Du Plessis, 2009b). These two spheres interact to create the dynamics of a city and therefore urban resilience needs to consider not just biophysical or social resilience, but also the interactions between them. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects.

This paper explores the interdependencies between resilience in the social and biophysical systems of the South African city through the use of scenarios constructed from an

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individual’s perspective of three recent events in South Africa. These scenarios are based within the City of Tshwane as a model apartheid city.

2. Approach

The approach used to explore the interdependencies of urban and social resilience is formative scenario analysis. Formative scenarios can be a useful tool to guide one towards a differentiated and structured understanding of a case’s current state and its dynamics. Comprising of a sufficient set of impact variables and the linkages of these variables to gain a valid description, scenarios are useful tools to gain insights into a case and its potential developments and dynamics (Scholz and Tietje, 2002 pp80-85).

The three scenarios constructed in this paper are based on real events and conditions experienced by citizens of the City of Tshwane as a typical South African city and are formulated from an individual perspective. These scenarios were based on news articles, interviews and engagement with the subjects involved. In the next section we examine the literature on resilience. Both social and urban resilience are examined to see whether there is a juncture between them or not.

3. Resilience

Resilience was first used as a term in engineering in the field of material sciences to describe the ability to store strain energy and deflect elastically under a load without breaking or being deformed (Plodinec, 2009). The Resilience perspective grew in the 1970s and 1980s to include ecological as well as psychological interpretations of resilience. In terms of the ecological resilience perspective the term was used to describe the capacity of ecosystems to recover from environmental stresses (Holling 1973; Abel and Stepp, 2001; Resilience Alliance, 2006; Jentsch et al, 2011) and emerged due to the dissatisfaction with other existing models of ecosystem change (Cote and Nightingale, 2012). However, this equilibrist model of resilience has been questioned, as in practice ecological recovery does not inevitably entail a return to the system’s original state. The understanding of resilience has subsequently been expanded to a more evolutionary model that acknowledges the ability of the system to adapt and transform to a new state of being while still maintaining previous functions (Kirmayer et al., 2009 pp64; Zolli and Healy, 2012 pp13). The main characteristics therefore of ecological resilience are adaptation, transformation and continued functioning (Waller, 2001).

From this point of departure, it is suggested (Carpenter et al. 2001:766) that the resilience of social-ecological systems has a three part definition: the amount of disturbance a system can absorb and still remain within the same state or domain of attraction; the degree to which the system is capable of self-reorganisation; and the degree to which the system can build and increase the capacity for learning and adaptation.

In psychology the concept of social resilience developed in parallel, with focus on the strengths that people and systems demonstrate that enable them to rise above adversity (DuPlessis Van Breda, 2001; Masten and Obradovic, 2006). As with ecological resilience, it
developed out of dissatisfaction with the distorted focus on vulnerability and deficit models and not on strengths and adaptability. The concept of individual resilience expanded to include family resilience, community resilience, as well as broader social resilience. However, there is as yet little integration between the work on social resilience and the resilience of social-ecological systems.

In the following sections we will discuss the emphases that urban resilience (focusing on climate proofing, disasters etc.) and social resilience (focusing on the individual, family, community and society) has taken in practice.

3.1 Urban resilience

The development of assessment systems or planning guidelines for urban resilience introduces concepts such as diversity, redundancy, modularity and interdependence of system components, feedback sensitivity and capacity for adaptation to the planning lexicon. However, there is still no consensus about what these and other resilience thinking concepts actually mean when applied to cities.

Urban resilience research has been centred on climate proofing (see Muller, 2007; Tomkins and Adger, 2004 and Newman et al, 2009), disasters such as flooding (see Lamond and Proverbs, 2009), oil spills (see Dow, 2010), terrorism (Coaffee, 2009; Coaffee and Wood, 2006) as well as sea level rise (see Muller, 2007). These are very specific disturbances to the urban system and fail to take into account the complexity and interdependence of all the social, ecological, economic, political and physical aspects of an urban environment that contributes to its general resilience. These studies also tend to focus on the vulnerability of the exterior or physical aspects of the city such as its infrastructure or ecosystem services and the concomitant strengths and vulnerabilities in the economic or political structures of the city. They rarely look at the relationship between the systems of the city (whether institutional, biophysical or economic) and social resilience.

3.2 Social resilience

Social resilience can broadly be grouped into four strata consisting of individual resilience at the base, family resilience, community resilience and then broader social resilience of communities incorporating towns, cities and even entire nations (Kirmayer et al., 2009). Figure 1 describes the components of broader social resilience that will be discussed in this section.
### 3.2.1 Individual resilience

Individual resilience or personal resilience could be seen as the basis of societal resilience building the upper strata of social resilience (Kirmayer, et al., 2009). Individual resilience focusses on an individual’s personality traits and capabilities (personal abilities and cognitive strategies) of adaptability and transformation (Lemay and Ghazal, 2001; Rutter, 2007; Tugade et al, 2004; Kirmayer et al., 2009; Hefferson and Boniwell, 2010).

When considering individual personality traits there is an abundance of literature on various different sets. We therefore focus on certain key traits that have reference to several others: self-efficacy, confidence, hope and optimism. Confidence can be defined as the “individual's conviction...about his or her abilities to mobilize the motivation, cognitive resources, and courses of action needed to successfully execute a specific task within a given context”. Confidence can be seen as a positive psychological capacity (Luthans et al., 2004 pp47).

Hope is also seen as an indispensable trait for both individuals as well as communities. Hope is the capacity of an individual to conceptualise goals, develop pathways to achieve these goals; and initiate and sustain the motivation required to achieve them (Snyder et al. 2002; Morrow, 2010; Braithwaite, 2004). Optimism is another individual resilience trait in positive psychology that comes from Seligman’s theory of learned optimism. Seligman’s (2002) definition focuses on permanence of events and pervasiveness. Permanence, in this case, refers to the perceived permanency of events in terms of time. Pervasiveness has to do with significance. For bad events, “optimists make specific attributions, while pessimists make universal attributions” (Luthans et al., 2004 pp45; Hefferson and Boniwell, 2011 pp117).

Resilience in terms of personal capabilities depend on mental operations and mediating processes that reflect personal agency, self-efficacy, idiosyncratic habits, coping mechanisms, mental sets, and the ways that people deal with challenges (Bandura, 1982; Rutter, 2007; Kirmayer et al., 2009).

### 3.2.2 Family resilience

Resilient individuals influence the resilience of a family system and the inverse is also true. A family unit can be seen as a self-regulating system that interacts with a larger community, social system, ecology or urban environment (Kirmayer et al., 2009, pp70-71). As with individual resilience, a family unit adjusts its roles, goals, values, rules, and priorities according to external changes in order to achieve and maintain certain levels of balance and harmony, as well as to transform or bounce back. In terms of general family resilience great emphasis is placed on a supportive environment for the individuals within the family unit as well as the support the family receives from outside such as schools, community members, religious institutions, government and others (Kirmayer, et al., 2009).

Culture and ethnic identity is another important support to enhance family resilience. It is a grounding element that supports families in times of rapid change and could be a source of stability. Protective factors like cultural knowledge and practices allow for both flexibility and
consistency, which are key components of both individual and family resilience (Kirmayer, et al., 2009, pp71). Key steps towards creating resilient families would be to establish supportive communication networks, build emotional capacity, support spirituality, foster community relationships and to cultivate collective objectives or goals (Kirmayer et al., 2009).

3.2.3 Community and broader social resilience

Individuals and families do not exist in isolation and are part of a complex web of relationship within their environment. Community resilience accentuates assets or resource adaptability, collective processes such as collective hope and strengths such as social cohesion and trust (Kirmayer et al., 2009).

Resource adaptability (asset based resilience) focuses on the quality and quantity of resources accessible to the community and the extent to which these resources can be modified to meet changing social environments and adapt to breakdown in the system, and build on the strengths of such a community (Adger, 2003). These resources take account of not only physical resources but also social resources such as the individuals, networks and other associations that individuals or families would not necessarily have access to if they were not included in this community. However this view is over simplified, only taking stock of resources but failing to consider the interactions between these resources as something of consequence.

Collective processes linked to resilience incorporate visioning and collective hope. Visioning give both individuals and communities an opportunity “to express how they wish the world to be” and therefore make allowance for collective hope (Morrow, 2010, pp6). Sustainable collective action requires individuals to genuinely buy into the collective hope process with a shared vision of desired social change and a belief that change can happen (Braithwaite, 2004). Collective hope has to provide a framework for understanding how individual hopes are coordinated into a common aspiration and then into collective action (McGeer, 2004). It is therefore essential that all involved recognise that “others care about their well-being; that the society will help deal with the desired goals; that resources are available; and that the goal is worthy” (Braithwaite, 2004). If their goals are not reached it is also important to review and build onto these aspirations to keep the collective hope operating (McGeer, 2004).

Social cohesion is linked to the collective processes and is also an important element of social resilience. Social cohesion is a set of social processes that focuses on the feelings of solidarity between citizens, development of shared values, equal opportunity, feelings of involvement within the community, cooperation with other people as well as institutions and place attachment (Jenson, 1998). This also links to aspects of trust in one another, as well as trust in the government’s capabilities and integrity.

As with urban resilience, social resilience has thus far focussed mainly on interrelations between social strata with few linkages to the properties in the urban environment and when it attempted such linkages (e.g. asset based resilience), the complexity of the interactions
were disregarded. In the next section we elaborate on the linkages with the urban resilience of South African cities.

4. Reciprocity of South African urban and social resilience

To explore the possible reciprocal relationships between urban and social resilience, we will discuss a few scenarios in which the interdependencies between urban and social resilience are illustrated. These scenarios are based on real events and conditions experienced by the City of Tshwane as a typical South African city and are discussed from an individual perspective.

Illustration of urban-social interdependency – Soshanguve train

_Nombeko is a 39 year old single mother who lives in the dormitory township of Soshanguve with her four children. She travels to inner city (35km from the train station) to work as a domestic worker. She leaves home at five in the morning to be at work at seven. Walking 8km to the Mabopane station she arrives to find the train late, at the arrival of the train 50 minutes later she gets onto the train. Ten minutes later the train unexpectedly stops in the middle of nowhere. In the confusion she gets out of the train to see a train support vehicle stopping next to the train and a minute later dash away with the train driver. She stands back hopelessly as her fellow commuters, outraged by the continued poor service delivery, set fire to the train. She has to walk home and let her employer know that she will not be able to come to work as taking a minibus taxi would equate to her day’s pay. The next morning she hears that Metro Rail has discontinued services to Mapobane in the face of severe threats to the safety of their personnel, damage to infrastructure and losses of rolling stock due to a number of similar incidents in the past couple of years. This leaves only the unaffordable taxi as an alternative means of transport._

If we consider the factors at hand, the low adaptive capacity of the physical environment maintains the isolation of Soshanguve and the failure of the urban environment to provide the urban poor with equal access to economic opportunities within the city. Current development by the metro council according to national guidelines situates affordable housing infrastructure predominantly in the old townships located on the city periphery, a practice which further entrenches the spatial segregation of the poor in isolated areas far from any economic opportunities (Vanderschuren and Galaria, 2003:268). It is unfeasible for the private sector to invest in Soshanguve as the area has low connectivity and low economic opportunity. The inhabitants then become dependent on work elsewhere in the city. However, Tshwane’s spatial structure necessitates long travelling distances and with the low densities of the city, this makes public transport unaffordable and limited viable public transport options are available to the people in these isolated areas, lowering the adaptive capacity of the transport system.

This physical rigidity then influences the social resilience as these poor communities are fixed in an area with low opportunities, increasing their vulnerability to factors such as increased transportation costs or the failure of transport systems. The social resilience of these communities falters as their assets (such as their transport system) fail. When the
transport infrastructure, like the train, comes to a stop there are not sufficient or cost-effective alternatives for people like Nombeko to continue functioning as she did previously. People lose trust in their government’s ability (or willingness) to provide for them or care about their well-being and their personal goals, and feel exploited. The social cohesion weakens as the cooperation with other people and explicitly government institutions weakens and people lose their attachment to place (Jenson, 1998). They then respond from a place of anger, resulting in social unrest and even mob justice through actions such as burning trains and threatening train drivers. This then in turn influences the ability of the physical environment to function as infrastructure is damaged or destroyed. Replacing and repairing infrastructure place a further economic burden on the city and displace funds from other service delivery programmes such as the provision of affordable housing.

Illustration of urban-social interdependency – Plastic View squatters

Alakhe is a 36 year old man who settled with his family in an informal settlement on a vacant plot within walking distance of the work he acquired as a gardener in a prestigious golf estate. It was a tossup for the family between living in the outskirts of the city with low probabilities of finding employment and staying close to work but with no running water or electricity. They opted for proximity. Their shack (informal built structure) made of corrugated sheeting wasn’t much but it was home. His wife and he could easily get to work and shops however their children could not go to any schools nearby and stayed at home. Coming home from work one day he arrives at a mess of smoke and bewildered occupants. Anguished over the safety of his family he starts negotiating his way through the huddle and finds his wife and kids settled atop a pile of their belongings in the field adjacent the burning settlement. Perplexed he listened to his wife’s account of how the police came into their home and chased them out with just enough time to grab their belongings before they set their shack alight and started to burn shack after shack. They slept in the field that night as they were rendered homeless. The next morning he hears that the home owners’ associations in the adjacent affluent (and influential) areas were putting pressure on the council to move them and that the Metro wants to relocate them to some far off area.

After this disruption in the community the informal settlers stood together and took the government to court with the help of a local NGO. Six years down the line, after standing together as a community, the 865 households were given the right to stay, and Plastic View will be formalised.

If we reflect on the dynamics in this scenario, the urban poor communities are adapting to the existing state of affairs, as described in the Soshanguve scenario. The result is an infiltration of the informal into the formal settlement areas. As the government fails to provide them with affordable housing close to job opportunities, the poor locate themselves close to job opportunities at the cost of other social amenities and access to basic services.

The ability of the political environment to resolve this issue is restricted due to the rigidity of strict policy and land use management systems and larger economic forces that effectively prohibits a diverse range of housing options. Additional forces in terms of land markets and
social pressures demand that government take action, and eventually the Metro respond to these pressures by forcefully removing illegal squatters.

The community’s social resilience is tested by the actions taken by government as their shacks are destroyed. However this community’s solidarity and cooperation with each other and institutions like the NGO, cultivated the community’s resilience. They took action toward a collective goal and confronted the council in court and won. Which in turn influenced the physical environment, as the council now has to provide formal low cost housing. By formalising Plastic View, the community may now have access to job opportunities, but these are still lowly paid and the costs of formal housing (rates and taxes, basic services) will place a heavy demand on disposable income. There are also no public health facilities or affordable schools in the vicinity which greatly reduces the personal resilience of people staying in these informal settlements. Furthermore, Plastic View is located on a floodplain, making it vulnerable to (and contributing to) the documented increases in flash flooding as a result of hardening of urban surfaces and the increased rainfall and strong storm events some are attributing to climate change (Cox et al., 2004). Thus an intervention which aimed at resolving one pressing issue may actually reduce the broader economic resilience of the individual and the small community.

Illustration of urban-social interdependency – Backyard shacks

Msizi is a 45 year old male, who stays in Mamelodi Township which he has made his home with his wife and two children. He has been on the waiting list for a free government provided house in Mamelodi for almost ten years now. With the cost of formal rental accommodation disproportionately high in terms of his income, he lives (like many other locals with little income) in a backyard shack. Dissatisfied with waiting for government to provide him with a house, he feels no remorse at the illegal connections of electricity to his backyard shack or the hosepipe they run from the public tap. However, the shared ventilated improved pit latrine cannot cope with the sixteen people living on the stand, resulting in a number of health problems for his family.

If we reveal the dynamic forces, the political and economic environment retains low capacity for providing housing for the poor. The delivery of subsidised housing units has time and again failed to reach the annual target of 300,000 houses per year, with for example only 161,854 housing units and 64,362 serviced sites delivered in 2009/10 (Khumalo, 2012. pp15), while a large young and unemployed populace continue increasing the backlog. According to recent statistics approximately a third of the youth (15-24 years) were neither employed, nor in education or training (StatsSA, 2012).

The social resilience is then affected as poor communities have no alternative formal housing. The community’s resource adaptability focuses on the quality and quantity of resources accessible to the community and the extent to which these resources can be modified to meet changing environments (Adger, 2003). These backyard shacks build onto the existing infrastructure and resources to fulfil a housing demand (Poulsen and Silverman, 2012), thereby encouraging the infiltration of informality into the formal settlement. Unlike the informal settlements, backyard shacks reduces the housing demand in areas demarcated for
residential use, which are serviced and have access to social amenities. However, this informal social intervention then places additional pressures on the resilience of the physical environment, especially municipal services, as these areas were not serviced to accommodate these numbers (Poulsen and Silverman, 2012). This could ultimately lead to poor service delivery which could subsequently lead to other social dilemmas such as outbreaks of diseases such as cholera or social unrest such as described in the Soshanguve train scenario.

5. Conclusion

In the literature on social and urban resilience we have found a disjuncture between the two aspects of the social-ecological system. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects. The formative scenarios illustrated how resilience of both the biophysical system (spatial segregation), as well as the social structures (housing subsidy schemes) leads to the rigidity of these systems, which in turn impacts on the resilience of smaller scale systems. These scenarios illustrated how the biophysical system’s resilience can influence social resilience and similarly how social resilience at smaller scales can influence the resilience of the larger system. With the rigid biophysical and institutional system, individuals are forced to self-organise. However this self-organisation then place pressures on the biophysical system, as well as the larger social system. These pressures could lead to a breakdown in the urban system and the social response then impacts the system in other ways. It is suggested that researchers in urban resilience should incorporate social resilience in their study of the biophysical aspects and social resilience should consider the influence of exterior aspects of the city on social resilience. It is the interdependencies of these systems and their ability to work together and adapt when other systems falters, that strengthen or reduce urban resilience.

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Bibliography


Abstract

As the world faces increasing threat of natural disasters, temporary housing has become an important transitional space to assist disaster refugees in rebuilding their lives. This study explores on how to measure the performance of temporary housing. After the 2009 Typhoon Morakot disaster in Taiwan, a non-profit organization in southern Taiwan constructed two types of single-story temporary houses. The participants were people who resided in these houses. This research first employed a social science study of questionnaire survey and participant observations on their life satisfaction. Engineering measurements to evaluate and compare these two environmental deficiency identified by the survey follows. The results showed that although most residents were satisfied with the overall environment, poor sound and heat insulation were common problems in temporary houses. In one type of the houses, indoor temperature may be higher than the outdoor temperature in summer. Both types of houses only have acoustic impedance between 15 to 30 dB for neighbouring unit partition walls, way below the standard for new buildings of 55 dB. It is considered that fast-build temporary houses that are improperly designed and constructed may not provide a suitable living environment for refugees to begin the recovery process inside.

Keywords: living satisfaction, temporary housing, heat insulation, sound insulation

1. INTRODUCTION

During the 2009 Typhoon Morakot disaster in Taiwan, consecutive rainfall over three days exceeded 2500 mm, the highest rainfall level recorded on the island. The compound disasters of flooding and landslides caused serious damage to the buildings in the mountains. Subsequently, numerous aboriginal tribes were resettled in temporary housing on the plain near the disaster-stricken mountain areas for a couple of years in preparation for permanent housing settlement. However, the temporary houses provided varied and the residents’ living backgrounds were also different. This led to numerous problems in the temporary housing
camp, which had not been considered beforehand, such as excessive building usage and living problems.

Although the public and private sectors were experienced with temporary housing because of the 1999 Chi-Chi earthquake disaster in Taiwan, the government had not established appropriate principles or guidelines for future applications. The government had been criticized previously for a lack of alertness and preparedness to respond to large-scale flooding. Therefore, after the Morakot flood, the central and local government debated whether to provide temporary housing and what form of temporary housing to construct (The Control Yuan of The Republic of China, 2000). Thus, when the decision to build a number of temporary houses was finally made, there was little time to develop a quality design.

A non-profit organization (NPO) in southern Taiwan assisted in constructing two types of single-story temporary houses namely remodelled military barracks with wooden roof trusses and prefabricated light-gauge steel houses. This study examines the residents’ satisfaction of the living environment in them. We first conducted a questionnaire survey to explore the residents’ level of satisfaction. After analyzing the survey results, we further quantified the negative factors that caused the refugees discomfort in the temporary houses using physical environment measurements.

2. RESEARCH SUBJECT AND METHODOLOGY

2.1 Subject

This study selected the Chung-Cheng Resettlement Center (CCRC) constructed by an NPO in Pingtung of southern Taiwan as the study site. This was because the CCRC provides 91 remodelled military barracks and 20 steel houses as temporary housing for aboriginal tribal families (Figs. 1). Every house is approximately 50 square meter and equipped with a living room, a kitchen, a bathroom, and three bedrooms. The remodelled military barracks, featuring wooden trusses and brick walls, were of a similar size and layout to the newly built light-gauge steel houses, enabling us to conduct a comparative study of the advantages and disadvantages these housing types. The CCRC houses 44 households (166 individuals) from Taiwu Township and 67 households (333 individuals) from Laiyi Township. The resettlement period was from January 1, 2010, through to December 31, 2011. Initially we explored the refugees’ lives periodically; however, 12 months after resettlement, when their lives had somewhat stabilized, we conducted questionnaires with the refugees under the permission of the management committee.
2.2 Methodology

As discussed previously, residents’ safety, health, convenience, and comfort are the basic requirements for houses. We established 12 evaluation criteria for living environment by referencing the results of our literature review. After the questionnaire survey, we used SPSS version 10.0 and a t-test to analyze the questionnaire responses.

The survey results suggested that the residents were most dissatisfied with two items in the physical environment. Therefore, we endeavored to quantify this phenomenon by measuring the remodeled military barracks and the steel houses. Thus, we can collect quantifiable data to improve future temporary housing.

3. RESEARCH FINDINGS AND DISCUSSION

3.1 Residents’ satisfaction level on living environment

We conducted the questionnaire using the census method, distributing questionnaires to 111 households. The survey period was one week from December 22, 2010, to December 28, 2010. We received 96 completed questionnaires for an overall response rate of 86.5%. The questionnaires that were incomplete or answered by minors, we eliminated. Thus, the number of valid questionnaires was 91, which accounted for 82% of the residents. Cronbach’s α was 0.93, higher than 0.7, which indicates that the questionnaire survey had a high credibility.

1. Satisfaction level on living environment
The result for residents’ satisfaction with the living environment was 3.74, which is between neutral and satisfied. The daylight criterion achieved the highest satisfaction level. These results suggest that temporary housing meets the refugees’ needs to some extent. However, sound insulation receives the lowest satisfaction level, followed by waterproofing and indoor temperature. These results indicate that the quality of the living environment of temporary housing still requires improvements (Fig. 2).

![Figure 2](image)

Figure 2. Analysis of the living environment of temporary housing

Residents living in the remodeled military barracks reported that on rainy days, the building had inundation problems. Following the onsite survey, we identified the primary factor contributing to the overflow of water was poor drainage systems, which could not drain at sufficient speed, causing inundation. Thus, 12 residents residing in remodeled military barracks experienced water overflowing into their houses because of heavy rain. In contrast to the remodeled barracks, inundation did not occur in the newly built steel houses because the design included a raised foundation and a comprehensive drainage system. In March 2011, the drainage problem was significantly improved after the government approved an upgrade budget.

Seven residents stated that the sound insulation of the temporary houses was poor; the primary noise source was their neighbors. This occurred in both steel houses and remodeled military barracks units. To understand how this affected the residents, we conducted an acoustic assessment to evaluate the sound insulation of the unit.

Regarding the indoor temperature, four respondents complained of overheating inside both types of temporary houses. Because the fluctuation of the indoor temperature is related to the airflow, we conducted an onsite indoor temperature and airflow experiment to examine the thermal insulation performance of both housing types.

2. Analysis of various levels of satisfaction with the living environment
Comparing the satisfaction level of residents living in remodeled military barracks with that of residents living in steel houses, the mean satisfaction level for people living in remodeled military barracks was 3.52, and the standard deviation was 0.71. The mean satisfaction level of the residents living in steel houses was 4.49, and the standard deviation was 0.62. The independent samples t-test showed that the residents living in steel houses were more satisfied with the living environment compared to their counterparts.

We then further analyzed the living environment evaluation criteria individually. The mean of the evaluation criteria for the steel houses was higher than that of the existing remodeled military barracks. The difference analysis conducted using a t-test found no obvious differences. This indicates that the satisfaction of residents living in steel houses is higher than that of the residents living in remodeled barracks.

According to the evaluation result, the sound insulation criterion achieved the lowest satisfaction level among residents of both the existing remodeled military barracks and the newly built steel houses. Refugees residing in both housing types experienced excessive indoor temperatures. Relevant authorities should examine the factors contributing to overheating problems and develop countermeasures to reduce these problems (Fig. 3).

Figure 3. Temporary housing residents’ evaluation of the living environment

3.2 Physical environment impact factors of different forms of housing

1. Sound environment analysis

We conducted an onsite test of the internal partition walls between two units of remodeled military barracks and steel houses to quantify the sound insulation performance. The sound insulation testing was based on EN ISO 140-4: 1998. We selected one remodeled military barracks and one steel house partition wall for testing (Figs. 4 and 5). The test result indicated that the transmission loss through the partition walls of the remodeled military barracks was 26 dB at 500Hz. At low-frequency
between 63.80 and 100 Hz, the resonate pattern was obvious, and the sound insulation volume decreased. The transmission loss of the steelhouse was 15 dB under 500 Hz, and the resonate pattern appeared at 125, 160, 2500, and 3500 Hz. The sound insulation volume also decreased. However, building codes in Taiwan only regulate the elements, materials, and thickness of the sound proofing walls; they do not specify the sound insulation performance level. Thus, we compared the data obtained in this study with that of commonly used 15-mm-thick RC partition walls in a laboratory to assess the sound insulation performance of the temporary houses (Fig. 6).

Regarding the airborne sound insulation of buildings and building elements, the basic sound insulation level of internal walls must reach D-40, which means that noise at 125 Hz should be reduced to 25 dB, 500 Hz should be reduced to 40 dB, and 2000 Hz should be reduced to 50 dB, according to the JIS A 1416. The results of the onsite tests on the internal walls of the remodeled military barracks revealed that the transmission loss was 15 dB at 125 Hz, 23 dB
at 500 Hz, and 36 dB at 2000 Hz. The test result on the internal walls of the steel house revealed that the transmission loss was 2 dB at 125 Hz, 13 dB at 500 Hz, and 27 dB at 2000 Hz. Both housing types have a transmission loss that is significantly lower than the minimum standard; thus, they do not meet the JIS requirement.

We also applied EN ISO 140-4 to compare the sound insulation performance of various construction methods. For the normalized level difference, the Dn value of the remodeled military barracks was 29 dB, the prefabricated steel house was 15 dB, and the 15-cm RC wall was 50 dB. The value for the 15-cm RC wall was significantly higher than that of the other two building types, demonstrating the low sound insulation capability of the temporary houses. Similar results were obtained for the standardized level, DnT, and apparent reduction index R as shown in Fig. 6.

Figure 6. Comparison of the sound insulation performance of temporary houses

The sound insulation performance exhibited a resonate pattern under 100 Hz. This means that the thickness and weight of partition walls of the remodeled military barracks were insufficient, resulting in low-frequency resonance. This also led to the poor sound insulation performance of the partition walls. The wooden frame of the partition walls were composed of 25 × 45 mm square timbers. The centre of the walls was filled with 64K rockwool. The walls are flanked by 12-mm magnesium oxide boards. The thickness of the internal walls was approximately 7.5 cm.

Another reason for the poor sound insulation performance was that the suspended ceiling was constructed before the partition walls because of the limited time before the refugees moved in. Therefore, the partition walls did not reach the roof; instead they terminated at the soffit of the suspended ceiling. Additionally, the opening between the trusses above the suspended ceiling was not filled with sound-proofing rockwool nor equipped with flanking plates. Thus, the truss opening above the partition walls may provide an acoustic transmission passage. All these problems resulted in poor sound insulation and frequent noise interference among different units in the same building (Fig. 7).
The thickness of the internal wall in the steel house was 5 cm, and the main element of the wall is polyester foam. The wall was flanked by two 0.3-mm steel plates. The material of the wall also had a poor sound insulation performance. Furthermore, the material was not sufficiently thick or heavy, resulting in poor soundproofing in the steel house. Another disadvantage is that above the suspended ceiling, similar to the remodelled barracks, the partition wall plate only reached the bottom cord of the space truss. The opening in the truss was not equipped with sound insulation blanking plates. The sound may transmit through the truss opening and the wall plates. A schematic diagram of the sound transmission through the truss opening and the wall plates is shown in Fig. 8.

![Diagram of sound transmission profile of the remodelled military barracks](image)

**Figure 7. Sound transmission profile of the remodelled military barracks**

![Diagram of sound transmission profile of the steel house](image)

**Figure 8. Sound transmission profile of the steel house**

2. Thermal environment analysis

According to the questionnaire survey, overheating of the indoor environment was the second major problem experienced by the temporary housing residents. Therefore, this study investigated the fluctuations of the indoor thermal condition during August, the hottest month in Taiwan. We measured and recorded the internal and external temperature and humidity of the remodelled military barracks and the prefabricated steel house for one week in August 2011. The measurement time step was 10 min. All doors and windows were closed to create a windless experimental environment. The weather during the study period was sunny, which
Our records show that the average outdoor temperature in a typical summer week during the study period was 27.95°C, the highest temperature was 32.29°C, and the lowest was 24.1°C. Under the same weather conditions, the highest indoor temperature of the remodeled military barracks was 31.79°C, and the lowest was 25.11°C. The highest indoor temperature of the steel house was 34.97°C, and the lowest was 27.19°C. The average indoor temperature of the remodeled military barracks was lower than the average outdoor temperature, and the variation range was narrow, indicating that the existing reconstruction had some shading effect. Conversely, the indoor temperature of the prefabricated steel house was higher than the outdoor temperature. This explained the unbearably high temperatures in the steel houses and why residents were extremely uncomfortable. These results also indicate that the shading performance of the steel house requires further improvements (Fig.9).

![Comparison between the indoor temperatures of the temporary houses](image)

**Figure 9. Comparison between the indoor temperatures of the temporary houses**

4. CONCLUSION

Temporary houses not only relieve the tremendous stress felt by refugees of major disasters, but are also a starting point for post-disaster recovery. Thus, the condition of the living environment affects both the residents’ satisfaction with their quality of life and their post-disaster recovery. This study conducted questionnaire surveys in a campground with two types of temporary houses to evaluate residents’ satisfaction with their living environment. The results indicated that the residents of both types of houses were fairly satisfied with the overall living environment and particularly satisfied with the access to daylight, the lighting, and the layout. Through a detailed analysis of the survey results, we found that the residents were least satisfied with the sound insulation and heat dissipation performance.
The poor sound insulation performance causes noise disturbance to neighboring households. Onsite sound insulation measurements indicated that both temporary housing types have minimal acoustic impedance between housing units. The three main factors that contributed to the poor performance were inappropriate choice of partition wall material, inadequate wall thickness, and the existence of an acoustic transmission channel above the suspended ceiling.

Poor heat dispersal resulted in overheated rooms, which also received a low satisfaction score from the residents. Using temperature measurements, we identified that the performance of the steel house was worse than that of the remodeled barracks because the average indoor temperature was always higher than the outdoor temperature.

References

The Performance of Houses in the Canterbury Earthquake Sequence

Graeme J Beattie

Abstract

Over the period from 4 September 2010 until late in 2011 the Canterbury region of New Zealand was subjected to a sequence of more than 10,000 earthquakes, four of which were large enough to have significant effect on the buildings and infrastructure in the area. The most devastating event occurred on 22 February 2011, where the 6.3 Richter magnitude earthquake was centred at a very shallow depth and very close to the central business district of Christchurch at lunchtime, resulting in 185 deaths. Much of the housing stock was subjected to either the effects of liquefaction (differential ground settlements and lateral spreading) or severe shaking. There were two deaths in the 150,000 houses and these were the result of a cliff collapse on to the properties.

In the latter half of 2011, BRANZ conducted a comprehensive survey of more than 300 houses located in Christchurch city to determine the effects of the earthquake on the housing stock and its ability to resist the seismic actions. The surveyed properties were randomly selected throughout Christchurch and this provided a range of house construction types and ages and also a range of soil conditions. This paper describes the analysis of the data obtained in the survey, giving consideration to the types and weights of construction materials, the style of house construction (foundation type, shape, number of storeys, etc) and the subsoil conditions, and relates the observed damage to these influencing factors. Recommendations are made on the dwelling likely to provide the best performance under earthquake attack.

Keywords: earthquake, seismic, house performance, survey

1. Introduction

At 4:35am local time on 4 September 2010, a magnitude 7.1 earthquake struck the Canterbury region of New Zealand (NZ). The earthquake was centred near the township of Darfield, a small country community approximately 40km west of the city of Christchurch, and its epicentre was at a depth of 10km. The shaking intensities in Christchurch were in the range of 0.16g to 0.65g peak ground acceleration (PGA) in the horizontal direction and 0.05g to 0.3g PGA in the vertical direction [Cousins & McVerry 2010]. Spectral accelerations were in the order of 0.8 times the design spectral acceleration in the frequency range of typical house structures. While the effect on Christchurch houses was generally the loss of

1 Principal Structural Engineer, BRANZ Ltd, Porirua, New Zealand; graeme.beattie@branz.co.nz
unreinforced masonry chimneys and some minor damage to interior linings, several areas were affected by ground liquefaction and associated lateral spreading.

Typically, a series of aftershocks occurred over the following months although none of these events caused further significant damage, until 12:51pm on 22 February 2011 when a 6.3 magnitude event struck beneath the urban area of the city. The epicentre was located 10km southeast of the central business district (CBD) and at a depth of 6km. The range of horizontal PGAs recorded in the urban area ranged from 0.2g to 1.41g and in the vertical direction, 0.06g to 2.21g [Bradley & Cubrinovski 2011].

Spectral accelerations relevant to typical New Zealand house structures in the February event were of the order of twice the design spectral accelerations in some parts of the city.

Further significant shallow events occurred on 13 June 2011 (magnitude 6.3) and 23 December 2011 (magnitude 6.0) with their epicentres located close to the 22 February epicentre. The events of 4 September 2010, 22 February 2011, 13 June 2011 and 23 December 2011 are referred to in this paper as the main events. Shaking activity has diminished significantly in the latter half of 2012 but 10,000 odd aftershocks have occurred over the period between 4 September 2010 and June 2012 and these have also served to rattle households.

This paper provides the results of a damage survey of a representative range of Christchurch houses that was undertaken over the period from July to September 2011. The survey therefore does not include the further damage sustained in some areas of the city during the 23 December 2011 event. The paper also draws on the experience of the four BRANZ structural engineers who were involved in the safety assessments of houses in the eastern and southern suburbs following the February 2011 event. It describes the response of typical NZ houses to the earthquake disaster and makes suggestions on improvements to house designs to provide greater resilience in such events.

2. Survey process

Following the 22 February 2011 event, BRANZ undertook a survey of 314 houses, randomly selected from within the boundaries of Christchurch city. The process involved randomly selecting a little more than 50 mesh blocks from the Statistics New Zealand census database [Statistics New Zealand]. Mesh blocks are roughly based on numbers of people residing within the block and generally represent an area a little larger than a residential block. Within each mesh block, six adjacent houses were selected for surveying at the southeast corner of each mesh block and the surveyors visited each property. Figure 1 shows the locations of the surveyed houses (yellow pins).
A team of two BRANZ representatives undertook the survey with a comprehensive survey form to gather observations about the site and its hazards (e.g., liquefied, rock-fall susceptible), house age, house style, construction materials, and then estimates were made of the extent of damage sustained by the various elements of the structure. If the occupier of a property was not at home, the surveyors moved to the next property adjacent and this was repeated until information was gathered from six houses in the block. The approximate total number of houses in Christchurch city is 150,000 and so approximately 0.2% of the total population was surveyed in this process. This paper presents the results of the survey.

3. SURVEY RESULTS

This section presents information gathered on the sites, the construction characteristics of the surveyed houses, and recorded damage.

3.1 The site

The majority of Christchurch city is situated on the flat Canterbury plains, but there has also been urban development on the Port Hills to the south of the CBD over the entire life of the city, with the hillside development making up approximately 10% of the total housing stock. The survey proportions of flat land and hillside houses match this ratio relatively well (Table 1).

<table>
<thead>
<tr>
<th>Degree of ground slope</th>
<th>Percentage of surveyed houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>86</td>
</tr>
<tr>
<td>Gentle</td>
<td>5</td>
</tr>
<tr>
<td>Steep</td>
<td>8</td>
</tr>
<tr>
<td>Hilltop</td>
<td>1</td>
</tr>
</tbody>
</table>
3.1.1 Liquefaction occurrence

Of the 270 properties surveyed on the flat, 81 sites (30% of the flat land properties) had experienced ground liquefaction in either one or more of the first three main earthquakes. All of these properties were subject to ground liquefaction in February 2011, 31% of these had also experienced liquefaction in September 2010 and 42% in June 2011. The ground liquefied at seventeen of these properties in all three events.

3.2 House Age and Style

The Christchurch housing stock comprises dwellings constructed from the latter part of the 19th century through to the present day. Five age bands were selected into which each house was placed. The bands were pre-1930, 1930 to 1959, 1960 to 1979, 1980 to 1999 and 2000 onwards. These age bands were chosen to represent distinct periods of development of standards for house construction in New Zealand. Prior to 1930 there were no standards. In the early 1930s the first regulatory standards were produced. These were largely prescriptive and based on typical construction styles in the USA. They were not always adopted by the local jurisdictions either. In the 1960s the timber framing standards were developed further in a series of model building bylaws. These were in use until 1978 when the first engineering based light timber framing standard (SANZ 1978) was published. A significant review and republication of this standard occurred in 1999. The percentages of houses surveyed from each of these five bands are given in Table 2.

Table 2: Percentages of the surveyed houses in the five age bands and breakdown of foundation type for each age band

<table>
<thead>
<tr>
<th>Age band</th>
<th>Percentage of surveyed houses</th>
<th>Percentage of slab on grade houses in the age band</th>
<th>Percentage of houses with perimeter foundations in the age band</th>
<th>Percentage of other foundation types in the age band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1930</td>
<td>14</td>
<td>2</td>
<td>65</td>
<td>33</td>
</tr>
<tr>
<td>1930-1959</td>
<td>24</td>
<td>5</td>
<td>87</td>
<td>8</td>
</tr>
<tr>
<td>1960-1979</td>
<td>33</td>
<td>21</td>
<td>79</td>
<td>0</td>
</tr>
<tr>
<td>1980-1999</td>
<td>15</td>
<td>63</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>2000 onwards</td>
<td>14</td>
<td>87</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>All ages</td>
<td>100</td>
<td>31</td>
<td>63</td>
<td>6</td>
</tr>
</tbody>
</table>

New Zealand houses are generally one or two storeys, but on hillsides it is common for there to be more than two storeys. Houses built to the NZ non-specific design standard, NZS 3604:2011 (SNZ 2011) and its predecessors are limited in height to a maximum of 10m and two and a half storeys, the half storey being in the roof space. Houses built outside of these (and other) requirements must be specifically designed.

In the survey population, 233 houses (74%) were single storey structures, 74 (24%) were two storey structures and 7 (2%) were three storey dwellings. Of the single storey dwellings, 58% were a simple rectangular shape, 31% were “L” shaped, 3% were “T” shaped and 8% were complex shapes. Of the 74 two storey dwellings surveyed, 55% were a simple
rectangular shape, 23% were “L” shaped, 5% were “T” shaped and 17% had a complex shape.

3.3 House Foundation Types

There are two major foundation types in use for house construction in Christchurch. Slab on grade floors have been the predominant construction style over the last 30 or so years for houses on the flat and also for some properties on the hills. This is confirmed from the survey of randomly chosen houses (Table 2). Over the early to mid 20th century, the preferred foundation style was a concrete perimeter foundation wall with concrete piles inside the perimeter. Such a style was typical on both the flat and the hills. In the hillside houses the floor was often supported on jack studs on short piles (Figure 1). Very occasionally houses were built entirely on timber piles in the early part of the 20th century.

![Jack studs beneath a hillside dwelling (tilt due to superstructure lateral displacement)](image)

3.4 House Superstructure

3.4.1 Structural frame

Of the 233 single storey dwellings surveyed, 228 were framed. It was not possible on most occasions to tell whether the framing was timber or light gauge steel, because the damage to the dwelling was insufficient to reveal the framing. However, light gauge steel framing is a relatively new construction type in NZ and therefore it is expected that the great majority of the surveyed houses had timber framing. The other five houses had either concrete, concrete masonry or unreinforced brick masonry walls. Of the 74 two storey dwellings surveyed, 80% had framed bottom storeys and 20% had either concrete or concrete masonry bottom storey walls. In all but one of these cases the top floor was framed.
3.4.2 Wall claddings

Several cladding systems are common in NZ. These include timber weatherboards, brick/block veneer and stucco, although the latter is much less common nowadays. Table shows the distributions of cladding on the surveyed houses. It can be seen that the totals for the lower and upper storeys of the two storey houses are greater than the 74 two storey houses surveyed. In both cases the reason is that on occasions there was more than one cladding type on a house.

Table 3: Distribution of wall cladding types on surveyed single and two storey houses

<table>
<thead>
<tr>
<th>Cladding type</th>
<th>Single storey houses</th>
<th>Two storey houses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower storey</td>
</tr>
<tr>
<td>Weatherboards</td>
<td>70 (30%)</td>
<td>28 (29%)</td>
</tr>
<tr>
<td>Brick/block veneer</td>
<td>128 (55%)</td>
<td>29 (31%)</td>
</tr>
<tr>
<td>Stucco</td>
<td>34 (14%)</td>
<td>8 (8%)</td>
</tr>
<tr>
<td>Ply or fibre cement sheets</td>
<td>10 (4%)</td>
<td>9 (9%)</td>
</tr>
<tr>
<td>Exterior insulating finishing system (EIFS)</td>
<td>7 (3%)</td>
<td>8 (8%)</td>
</tr>
<tr>
<td>Other</td>
<td>8 (3%)</td>
<td>13 (14%)</td>
</tr>
<tr>
<td>Total</td>
<td>233</td>
<td>95</td>
</tr>
</tbody>
</table>

3.4.3 Roof claddings

The most common roof claddings in use in NZ in the first half of the 20th century were corrugated steel and concrete tiles. In the last 60 years there has been an increase in the use of pressed metal tiles and clay tiles, although the use of heavy tiles in general has decreased over the last 30 years. Other systems such as rubber membranes, asphaltic tiles and shingles have been rarely used in NZ. Table provides a distribution of roof cladding types versus the age band of the house for the surveyed houses.

Table 4: Numbers of houses with roof cladding type for each age band

<table>
<thead>
<tr>
<th>Age band</th>
<th>Heavy tiles</th>
<th>Sheet cladding (eg corrugated steel)</th>
<th>Metal tiles</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1930</td>
<td>2 (3%)</td>
<td>37 (20%)</td>
<td>6 (12%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>1930-1959</td>
<td>29 (41%)</td>
<td>32 (17%)</td>
<td>11 (22%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>1960-1979</td>
<td>32 (45%)</td>
<td>57 (31%)</td>
<td>12 (24%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>1980-1999</td>
<td>5 (7%)</td>
<td>32 (17%)</td>
<td>8 (16%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>2000 onwards</td>
<td>3 (4%)</td>
<td>27 (15%)</td>
<td>12 (24%)</td>
<td>3 (34%)</td>
</tr>
<tr>
<td>Total</td>
<td>71 (100%)</td>
<td>185 (100%)</td>
<td>49 (100%)</td>
<td>9 (100%)</td>
</tr>
</tbody>
</table>

3.4.4 Interior linings

In the early 20th century and before, lathe and plaster was a common lining system for houses. This system continued to be used through until the 1940s. Gypsum based plasterboard was introduced in the late 1920s and has gone on to be the most popular lining
material at the present time. Fibrous plaster was also popular from the 1950s until the
1980s because it had a very smooth face for accepting wallpapers. Of the surveyed houses,
79% were lined with plasterboard, 18% with lathe and plaster, 8% with fibrous plaster and
8% with other linings. These percentages total to greater than 100% because on occasions
there was more than one lining type present in a single dwelling. Since the first publication
of NZS 3604 in 1978, plasterboard linings have fulfilled a bracing role in timber framed
houses. Prior to this bracing was provided by diagonal timber braces in the wall framing and
the plasterboard had a non-structural function.

3.5 Recorded Damage

Along with gathering information on the characteristics of the properties, estimates were
made of the levels of damage sustained by the various components of the dwellings.
Analysis of the gathered damage data is still going on. It is notable that no timber framed
houses collapsed in any of the earthquakes unless affected by ground movement such as
cliff collapses above or adjacent to houses or rolling rock impacts. It is also important to
remember that the performance expectation in the NZ Building Code (DBH 1992) is that
buildings should not collapse when subjected to what is referred to in the NZ loading
standards as the ultimate limit state loading condition. However, damage is expected to
occur to buildings in an event of this size. This condition was exceeded in many areas of the
city, particularly in the February 2011 event.

Of the 314 houses surveyed 167 were damaged in the September 2010 earthquake, 237 in
February 2011 and 136 in June 2011. It is not known when 20 houses were damaged. Only
10% of the houses surveyed had sustained no damage, but in many of the damaged houses
it was limited to joint cracks in plasterboard linings, and cracking in fibrous plaster or lathe
and plaster linings.

Much of the damage to houses on the flat was due to differential ground settlement and
lateral spreading associated with liquefaction and varied from quite minor to major (Figure
2). In houses not affected by ground liquefaction, the most obvious signs of house damage
viewed from the outside were failed unreinforced masonry chimneys on older houses and
the loss of portions of veneer.
In the hill suburbs, the shaking was more severe, resulting in substantial damage to brick veneer claddings, heavy tile roofs and interior linings.

### 3.5.1 Foundations

Slab on grade foundations performed well under earthquake shaking. However, ground deformations beneath these slabs, caused either by liquefaction settlement or lateral ground spreading on the flat or ground slumping in the hill suburbs, resulted in sometimes severe distortions of the concrete slabs. Of the surveyed properties, 81 had some evidence of liquefaction. Eighteen of these were slab on grade foundations and 14 were undamaged. The common perimeter concrete foundation with internal piles also fared well under ground shaking but was affected by varying degrees by the ground movement. It was common for these perimeter foundations to be unreinforced in the early to mid 20th century houses but most foundations constructed after this contained at least one 12mm diameter bar, often plain. Whether reinforced in this way or not, these foundations were unable to resist the ground deformations and fractured (Figure 3). Fifty seven of the surveyed properties with perimeter foundations were located where the ground had liquefied and 24 of these were undamaged.
Figure 3. Example of reinforced concrete perimeter foundation pulled apart by spreading ground

3.5.2 Wall cladding systems

Seventy two percent of the brick/block veneer claddings on the surveyed houses sustained damage, 76% of houses with stucco claddings and 67% of houses with monolithic claddings (eg plastered sheet materials and EIFS) (Table ). About a quarter of veneer clad houses had a significant proportion where cladding fell off or was detached or unstable. Almost all veneer clad buildings with more than 10% of cladding fallen, detached or unstable were in the hill suburbs, with the balance mostly being houses with separate unattached foundations for the brick veneer and the framing. Veneers constructed after the mid 1990’s performed much better than earlier construction because of improvements in the tie fixing systems to the framing that were introduced at that time.

The majority of houses surveyed with monolithic cladding suffered from some sort of cracking, but only 21 houses of this type were surveyed. Most of the cracking was from the corners of windows and experimental studies conducted at BRANZ some years earlier (Beattie 2006) had indicated that such damage was relatively easy to repair. The damage to weatherboard claddings was not specifically recorded because it was generally observed to be very low. As expected because of the greater ground distortion, the proportion of houses that had jammed doors or windows was higher in the areas that were affected by liquefaction than those that were not.

3.5.3 Roof claddings

Damage to sheet roof claddings and metal tiles was confined mainly to damage sustained from falling chimneys and tended to be minor. Concrete and clay tile roofs also sustained damage from falling chimneys but those in the hill suburbs often suffered from dislodgement of the tiles from the supporting battens (Figure 4). It was common for such tiles not to be
tied to the framing or for the ties (if they were present) to have corroded. Very high vertical peak ground accelerations (>1g) were recorded in February 2011 in the hill suburbs and this is sure to have contributed to the tile dislodgement.

**Table 5: Percentage of stucco, masonry and monolithically clad houses with different types of damage**

<table>
<thead>
<tr>
<th>Area of wall affected</th>
<th>% cracked</th>
<th>% fallen, detached or unstable</th>
<th>% with cracks over substrate joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;50%</td>
<td>10-49%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td></td>
<td>&gt;50%</td>
<td>10-49%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td></td>
<td>&gt;50%</td>
<td>10-49%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Stucco</td>
<td>10</td>
<td>26</td>
<td>38</td>
</tr>
<tr>
<td>Veneer</td>
<td>12</td>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>Monolithic</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>24</td>
<td>38</td>
</tr>
</tbody>
</table>

*Figure 4: Dislodged concrete roof tiles*

**3.5.4 Interior linings**

Eighty five percent of the surveyed houses had damage to wall linings and 73% had damage in the ceiling linings. Joint cracks were the most common form of damage, with 72% of houses suffering from them. Wall linings rarely became detached. Diagonal cracks were rare in houses that only had plasterboard linings. Most of the diagonal cracking that did occur in plasterboard appeared to be at the corners of openings, and some was observed in houses that suffered from severe sagging and hogging in the foundations due to ground movement.

As with wall linings, joint cracks were the most common form of damage in ceiling linings, with 49% of houses suffering from them. Diagonal cracks were not common in plasterboard ceilings but far more common (27%) in fibrous plaster ceilings. It is believed that because the fixing of the fibrous plaster ceilings is often more rigid than the plasterboard products (eg wadded connection to the framing), distortion of the supporting framing causes the diagonal cracks to occur. It was rare for whole sheets to fall from the ceiling or the walls, but popping of fixings occurred in about 10% of the surveyed houses.
Diagonal cracks were more common in wall linings than in ceiling linings. This is likely to be due to there being openings causing stress concentrations. NZ plasterboard manufacturers recommend fitting sheets around the corners of openings to provide a better finish performance during normal seasonal changes in the timber framing, which does make the sheets more susceptible to diagonal cracking than linings with joints coincident with the edge of the opening, as the walls rack in an earthquake.

4. Recommendations for improved performance

The survey results and also the observations made by the author and colleagues during the house safety evaluations provided an opportunity to form a view on the recipe for better performing houses.

Timber framed houses are particularly resilient, as borne out by their performance in this sequence of earthquake events, where none collapsed unless affected by rockfall or ground collapse. However, damage should be expected in earthquakes of this severity because distortion of the structure occurs as the earthquake energy is absorbed. Most of this damage is repairable at low to moderate cost but there are certain design approaches that can lessen the amount of damage.

Houses that were affected by ground distortion from liquefaction were shown to be better protected when a stiff foundation system such as a reinforced waffle slab was used, which could bridge over ground distortions without having excessive curvatures. Houses with heavy claddings clearly distorted more than those with lightweight claddings when the ground beneath them liquefied. Under shaking action alone, heavy houses can be designed to have stronger bracing systems to resist the greater inertial forces.

Simply shaped houses such as rectangular forms performed better than more complex forms. When complex forms are present, different parts of the house can clash with other parts under shaking actions. This is particularly obvious at the intersections of wings in an “L” or “U” shaped house, where damage was observed to be more severe.

Houses constructed on steeply sloping sites were more badly damaged when the foundation systems were not designed to properly cater for the potential stiffness incompatibility between the short and tall foundations. Similarly, hillside houses built with large windows to make the most of a view often suffered from a stiffness incompatibility between the view facing walls and the walls on the opposite side of the house, resulting in breakage of the windows. The provision of stiffer bracing systems for the view facing walls will serve to lessen these effects.

5. CONCLUSIONS

This paper has provided a brief description of the earthquakes that occurred in the Canterbury region over the period from 4 September 2010 until December 2011. It also discusses the types and proportions of house construction present in the city of Christchurch.
and then goes on to describe the results of a survey of 314 randomly selected houses over the period following the June 2011 earthquake.

The survey has shown that the performance of timber framed houses under the intense shaking has been good in terms of the performance expectations of the NZ Building Code. No collapses occurred directly from the shaking. However, damage was sustained by many of the houses, the majority of it reparable, but in some cases which were affected by significant liquefaction re-building will be necessary.

Several actions have been suggested to be taken in the design and construction of houses for improvement of their performance in earthquakes.

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The threat of slow changing disturbances to the resilience of African cities

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Abstract

Within rapidly urbanising South African cities, understanding the dynamics of change and the rate at which change occurs can be used to manage or regenerate parts of the urban system, and may provide effective tools for planning and monitoring ‘resilient’ development. A ‘resilience’ understanding may assist local authorities to transition toward cities that are more adaptive toward disasters, hazards and threats within flexible built environments. While most research conducted on the subject of urban resilience tackles issues relating to short-term disasters (pulse disturbances) like flooding, earthquakes, or terrorism, this paper focuses on the relationships between the more persistent issues or slow variables that occur over long periods of time (press disturbances). Examples explored within this paper include natural disasters, rapid urbanisation and urban poverty, environmental degradation, health and safety, crime, informal settlements, and lastly, policy implementation.

While change relating to press disturbances like informality, environmental degradation and urban poverty impacts all countries to some extent, the assumption is that Africa is most at risk since it is experiencing high rates of urbanisation within the context of pervasive poverty and inequality. These city environments may also not have the adaptive capacity to leverage these changes or steer their socio-economic and environmental systems beyond survivalist conditions. This paper tackles these topics from the perspective of an informal settlement called Plastic View in the City of Tshwane, South Africa – a country which has yet to regenerate its cities into integrated environments. It comprises of a desktop study of articles in the press to build an understanding of press disturbances affecting the focal system of Plastic View and their relationships and dynamics. The paper concludes with a motivation toward building a strategy for policy and housing management in the City of Tshwane that incorporates principles of resilience like adaptability, diversity and the acceptance of change as an important component for cities.

Keywords: Ecological resilience, Press disturbances, Slow Change, South Africa, Urban resilience.

1. Introduction

South African cities are characterised by complex and rapidly evolving environments within which the ideological legacy of past Apartheid planning still influences the functioning of the

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city, and where the new political regime has yet to inclusively repair and integrate the gaps left in the city fabric. Within the informality engendered by this transitioning society, niches appear in areas of opportunity and potential where a growing number of urban poor find their sources of livelihood and shelter. In particular, the City of Tshwane has seen the development of fast-growing informal settlements in close proximity to upmarket housing estates where the urban poor generate livelihoods from ad hoc job opportunities servicing the wealthy suburbs. Their presence has been the source of a tense relationship between stakeholders in the area, and efforts to resolve the situation through short-term interventions without a contextual understanding of the long-term pressures on the area, have failed. This poses the question whether broader issues are affecting these environments, and whether there is interplay between them that underlies the manner in which the system responds.

Framed in this background, this paper aims to understand the relationship between the various levels of press disturbances in the city panarchy from the perspective of an informal settlement called Plastic View. This understanding will be built from a desktop study of newspaper articles sourced over the last fifteen years, a time during which informal settlements have persisted in the city despite efforts to remove them. It is also based on observations of the focal area of Plastic View in order to build a deeper awareness of the complexity of the phenomenon.

1.1 A background to the concepts of resilience being discussed

Concepts of urban resilience are based on an understanding that as active components in city systems, human-beings are managers of various systems that are part of living systems comprising of humans and nature together, also referred to as a social-ecological system (SES) (Walker & Salt, 2006). The Tshwane SES is no different and as managers thereof, human beings have a responsibility to the city system. Viewing the Tshwane system as a holistic entity that is made up of various hierarchical scales of interaction and interrelation (Holling, Gunderson, & Peterson, 2002) proves useful. The interplay between various press and pulse disturbances therein, requires an understanding of where they sit in the various scales of the SES (the holarchy and panarchy) in which they occur. Looking for links between press and pulse disturbances in informal settlements is enriched by Koestler’s holarchic understanding of the relationship between components which themselves are whole, as well as elements in a bigger system within which they operate according to rules and patterns that determine their behaviour (Du Plessis, 2011). System properties emerge from the structural relationships and interactions of the components across different scales. These multi-scaled relationships are part of adaptive cycles that make up Holling’s panarchy, the theoretical framework that describes the multi-scaled dynamic relationships within the SES in question (Holling, Gunderson, & Peterson, 2002). Within the panarchy, the lowest scales undergo rapid change, while higher scales occur more slowly.

Resilience perspectives can prove to be useful, as they emerge from the exploration of integrated, post-sustainability outlooks that embrace the dynamics of change as a natural process, within which finite limits to resources can shift current environments into a completely different system state, but not erase it. In order to build resilience, we require an understanding of the forces driving the context, by asking resilience of what to what and
triggered by which disturbances (Resilience Alliance, 2010). In doing so, we may be able to actively build the adaptive capacity of the focal system to innovatively leverage change to release captured energy and resources, to cross a threshold into another more desirable system state, or for a shock to be absorbed without resulting in a system collapse.

If the current focal system is desired to be made more resilient, then attention should be given to increasing the functional diversity, so that it is able to demonstrate a number of different responses to pressure in the system while still maintaining its functionality. Understanding the relationship between multi-scale press disturbances offers an opportunity to open our thinking about city planning in the City of Tshwane into a holistic, long-term and less efficiency driven approach; one that strives for constant evaluation and evolution of the city since “resilience is the great moral quest of our age” (Zolli & Healy, 2012).

2. Contextualising Plastic View

2.1 Informality, the other face of life in the city

Since the establishment of a democratic South Africa in 1994, the country’s major cities have been experiencing an influx of migrants from rural areas and neighbouring African countries, into ‘townships’ and informal settlements on municipal lands (Soggot & Amupadhi, 1997). Within the Apartheid city planning strategy, racial segregation occurred by the deliberate separation of white, coloured and black neighbourhoods usually by natural features, industrial areas, or large distances. The word ‘township’ or ‘locations’ referred to ‘non-white’ neighbourhoods located in the city periphery and continues to be used in reference to these areas. Designed to be easily controlled as self-contained areas, they functioned separately from the ‘white’ city. ‘Townships’ played a crucial role in the formation of the apartheid city and embodied the complex process characterised as functional inclusion, spatial separation and political exclusion (Chipkin, 1998). After the system of control collapsed, South Africans of all races have been drawn to city life, however these urban areas are not always able to meet their needs for housing, employment and health within formal infrastructure frameworks - a trend prevalent the world over (Burdett & Sudjic, 2007). As the number of urban poor increases, so does the gap between the rich and poor in contemporary South African cities. Despite being dominated by strong African and global cosmopolitan influences the Afropolitan (Nuttall & Mbembe, 2008) the nature of our cities has been slow to bridge the social disconnect that continues in a number of forms like informal housing and trade, up-market security estates, car-dominant planning, increased crime and dwindling public amenities. Government investment into the ‘townships’ continues to be sustained with little affordable or alternative subsidised housing being provided in areas of the city where poorer residents want and need to be in order to sustain their livelihoods. In eighteen years of democracy, a high quality integrated housing scheme is yet to be realised in the eastern suburbs of Tshwane.

2.2 The eastern suburbs – home to Plastic View

Over the last fifteen years commercial and residential development and investment in the City of Tshwane has shifted eastward. The gated estate typology has been a dominant
response to the perceived security risk of living in older suburbs as well as a need for affordable medium density housing for middle income markets. A number of golf and equestrian themed estates have also drawn high-income earners to these suburbs that are characterised by large, physically cut-off and privately managed and serviced landholdings, which confine movement around them to car-dominated roads poorly serviced by public transport. They rely on malls, private schools and hospitals with little or no council led investment in amenities, infrastructure or public spaces. This typology results in pockets of left over land consisting of neglected municipal grounds, servitudes and natural areas. Socially and economically, the formation of at least ten fast-growing informal settlements developing in these ‘left over spaces’, are frustrating local communities (both in informal settlements and outside) who require clarity about the future. Most upmarket estates and households rely on a few low income workers to provide services as security guards, cleaners, domestic workers, gardeners, child minders, retail and construction workers and handymen. However, these estates offer no housing options for these marginal workers to live close to work nor has council provided alternative forms of housing in the area; workers are left to commute long distances to make their livelihoods, at high cost (Turok, Hunter, Robinson, Swilling, & van Ryneveld, 2011).

Development east of a suburb called Moreleta Park, has resulted in the emergence of informal settlements appropriating tracks of unmaintained, un-used, ‘out-of-sight’, yet well-located land in close proximity to estates. For the past few years tension between the Moreleta Park community and the growing number of vagrants has slowly been building up. The local community link criminal activity to the informal settlement, and cite the overcrowding and unsightly unhealthy living conditions, as reasons for their property investments declining (Roux, 2012). In turn, the vagrants cannot be legally evicted from the land without suitable alternative housing options being provided by council (Department of Housing, 1998).

Plastic View, the focal system of this paper, is an informal settlement located just east of Moreleta Park and is so dubbed because of its appearance when viewed from the major roads on its edges, as it seems to be made largely from salvaged plastic (Venter, 2012). It contains Woodlane Village, a settlement that was ‘organised’ by some of the informal settlers with the support of a local NGO group in 2008; and which comprises 856 households and roughly 3000 residents. Plastic View’s physical characteristics and location inform its emergence and resilience (Figure 1). The municipal land on which it is situated is roughly 9ha in size, of which portions are occupied by informal settlements (Woodlane being the largest) with the rest used for illegal dumping or left unattended. The land is confined by large roads on two of its edges (a regional road leading out of the city, as well as a neighbourhood connector) and various residential security estates along its remaining edges. It contains a perennial stream that connects to a larger open space system that runs through the eastern suburbs and connects to the large Rietvlei nature conservation area.
Residents of Plastic View say they have been living there since 2001, indicating that they settled there because of the need to be closer to job opportunities (Hlahla, 2010). It is also conveniently located next to wealthy estates, a large local church, a mall as well as an NGO. In the middle of 2012, the municipal land on which Plastic View is located was allocated for subsidised housing. This court decision resulted from persistent objections by the greater community against the rising number of vagrants in the areas, the effect on their investments (Roux, 2012), their subsequent concerns about the risk of a poor quality RDP housing scheme being built on the land, and human rights organisations protecting the settlers from eviction without suitable relocation as required by law (The Bill of Rights of the Constitution of the Republic of South Africa, 1996) (Department of Housing, 1998).

As Plastic View is poised for transition, the question is posed, how will formalisation affect its internal resilience as well as that of the broader community? The recent court order sets a precedent for the city; its response to informal settlements, alternative subsidised and affordable housing integration, and transformations to housing or planning policy will be interesting to follow. This phase of the Plastic View adaptive cycle offers a window of opportunity, a threshold between an existing system state and, possibly, a new improved one. Ignoring the interplay between deeper issues affecting the focal system in a hasty planning process may destroy the positive qualities of the landscape and place. Instead, alternative ways of proactively managing, coping and adapting to unpredictable change without having to reactively crisis manage, are required.

2.3 The Tshwane Panarchy, from the perspective of Plastic View

Gaining insight into the patterns of change and adaptation in Plastic View and the panarchy in which it sits, provides a platform to recognise where the linkages between press and pulse disturbances exist and their forms of interaction. Increasing this knowledge shapes awareness that settlements like Plastic View are not isolated from bigger forces, but are connected to both large scale issues pressuring the city, as well as small scale needs of its
citizens. To achieve this understanding, the panarchy of the City of Tshwane is divided into three scales; the Plastic View focal scale, the intermediate scale consisting of surrounding suburbs like Woodhill, Mooikloof and Moreleta Park, and lastly the highest scale consists of the Tshwane City Region and beyond. Within each of these scales, a chosen focal area may both respond to a disturbance and exert pressure on the system. In the case of Plastic View, it has emerged out of press disturbances from the City region scale, but also has pressured the intermediate scale of the surrounding neighbourhoods, as illustrated below:

![Figure 2: A diagrammatic representation of the Tshwane Panarchy, with Plastic View as the focal scale (Authors, 2012)](image)

3. Understanding multi-scale disturbances in the Panarchy

The Plastic View case study provides a useful way to appreciate the interaction and relationship between drivers and their influence on events across the panarchy of the city. This interlinked web shows strong connections between seemingly unrelated components, such as the emergence of informal settlements next to middle to high income suburbs in Tshwane. A deeper awareness of these intertwined issues may help in changing the perceptions of the community as a whole regarding their responsibility to each other and nurturing a respect for nature as an ecosystem of which they are a connected and integral part. This will be built out of the press disturbances impacting upon Plastic View over the three scales of the panarchy shown in Figure 2; the focal scale, the intermediate scale, and the large scale. A few of the most prominent disturbances will then be looked at to understand their system dynamics and multi-scale dynamics (Resilience Alliance, 2010).
3.1 Large-scale press disturbances that created Plastic View

To build an understanding of the multi-scale dynamics of the city panarchy, the first step begins with the forces driving the city- and national system and have led to the gaps formed in the city, which are points of vulnerability and opportunity. In Plastic View there are many press disturbances that have created its emergence; however a review of newspaper articles has narrowed the list down to three main issues.

The first relates to the Apartheid City plan and its structural legacy affecting the contemporary functioning of Tshwane (Herve, 2009). Its major effects are visible in the extensive distance between affordable housing located in former ‘townships’ and work opportunities within the wealthy suburbs. Tshwane is the metropolitan region with the longest commuting time (Turok, et al., 2011). The second is linked to the first, and deals with the lack of alternative affordable housing options for unskilled and semi-skilled workers in newer suburbs. Perhaps as a result of security estates not providing onsite staff accommodation (previously most homes in South Africa had staff quarters on the property). There is also the lack of council investment in integrated housing outside of the peripheral ‘townships’ (Herve, 2009). Thirdly, there is policy, which in practice has been slow to encourage the implementation of integrated human settlements close to job opportunities. The conditions related to the allocation of housing subsidies and legislation that prohibits the removal of settlers without providing alternative accommodation offers an opportunity for informal settlers to ‘jump the queue’ and get RDP housing after invading municipal land from which they cannot be evicted without receiving alternative housing (Department of Housing, 1994).

3.2 Press disturbances that Plastic View places on the larger system

The second step in understanding the panarchical relationships begins with an analysis of the pressures exerted by the focal system on the intermediate scale and also the large city scale. Progressively, Plastic View has grown and resisted a number of disturbances to its internal resilience (Roux, 2012). Concurrently, articles refer to the pressure that its presence is placing on surrounding communities and the overall system has grown too. Predominantly local communities have been concerned about the uncertain future of Plastic View; would it be removed, maintained or formalised? This is one of the drivers behind fragile market perceptions that adversely affect property prices in the area (pre-recession) and alienate local communities (Roux, 2012). The second driver is that the informal settlements are linked to criminal activity in the surrounding neighbourhoods, triggering higher security measures as responses and subsequently higher criminal violence. The third driver is the loss of ecosystem services and reduced quality of the natural environment. Lack of sanitation and increased water use from the streams on site for cleaning and washing has led to pollution of the water courses and has negatively affected the overall environmental quality on site including the open space systems to which these streams connect in the intermediate and city-wide scale. Lastly, the recent court decision to formalise Plastic View creates a precedent for the city regarding its response to other informal areas within the region (Venter, 2012).
3.3 Press disturbances that created pulse disturbances within Plastic View

The last step looks at pressures that have led to pulse disturbances occurring within Plastic View which have thus far been overcome by the community. The first pulse disturbance deals with seasonal natural disasters. Winter shack fires are a reality due to a lack of building controls, shacks are built too close to each other without fire breaks or insulation; and due to a lack of municipal investment in clean or alternative energy for poorer communities, paraffin lamps and open fires are sources of heat in winter (SAPA, 2012). In summer, floods are a source of crisis. Plastic View is located on a flood plain with two streams running through part of the site. During heavy rains, the Rietvlei Dam upstream, as well as the storm water runoff from vast expanses of hard surfaces surrounding the site compounds the increased water flow (Mail & Guardian, 2008). Executed by the local authority, forced evictions have been a source of pulse disturbances; rising tensions from the local community propelled forced removals of a number of informal settlements in the area. For example in 2006 a clean-up project carried out by Metro Police resulted in shacks and their belongings being burnt in an effort to remove the Plastic View informal settlement and the homeless without any alternative accommodation provided, nor a court interdict (Venter, 2012). Another incident was repeated in a nearby informal settlement in 2010, this time carried out by the ‘Red Ants’ joint venture security guards (Hlahla, 2010). In turn, this resulted in another pulse disturbance, that of local non-government organisations intervening on forced removals by organising and offering assistance to the affected community, propelling a court case to secure the informal settlement onsite until alternative housing could be provided. The last pulse disturbance identified in the desktop study is the court decision to formalise Plastic View, leaving the informal community excited to have ‘real homes at last’ (Du Preez, 2012). Thus far, the internal resilience of the informal community has been strong, showing high degrees of adaptability and capacity for the continual process of change that is one of the often ignored positive characteristics of informal settlements (Huchzermeyer, 2008). How formalisation will impact on this resilience remains to be seen.

3.4 Multi-scale disturbance relationships

Having found press disturbances that have, and continue to affect the focal system of Plastic View, we move toward building an understanding of the multi-scale relationships that exist between them and the specific pulse disturbances that drive the study area. As pressure on the system intensifies over a long period of time, a release or collapse is usually an opportunity for reinvention, but only if a deeper consideration of the interplay between forces is understood. In the following section we begin by looking at the relationships between disturbances by referring to Figure 3, and describing these in narrative form.
The Apartheid city plan continues to influence the functionality of the South African urban landscape (Issue 1), most prominently through limiting access as the ‘townships’ continue to be disconnected from other areas in the city. The nearest formal ‘township’ where many marginal workers live, is called Mamelodi and is located at least 20km away, too far to walk and too expensive to drive. The cost and time required to use public transport consumes a large percentage of disposable incomes, especially when many only have temporary jobs in Moreleta Park and need to be in the area in order to get more work or to cut their travel expenses (Hlahla, 2010). In addition, despite investment by most tiers of government from national to local to provide affordable housing (Issue 2) for the poor, it has largely been located in the traditionally ‘black townships’, adding to the difficulties faced by poorer people in getting to places of employment and generate livelihoods (Herve, 2009). With current policy promoting subsidised housing, as well as laws protecting tenants and squatters alike from eviction (Issue 3), the informal market has filled an essential gap in the city: providing flexible housing opportunities close to work opportunities. Unless there is a revision to planning schemes, and potentially the subsidised housing and eviction policy, innovative solutions for alternative affordable quality housing solutions for marginal urban South Africans are limited, unlike Elemental’s Quinta Monroy in Iquique, Chile (Elemental, 2001).

As general press disturbances intensify, they create conditions that make settlements like Plastic View possible. The presence of informal settlements next to high-income residential suburbs links back to Issues 1-3; these suburbs offer places of employment and opportunities to build a livelihood, as well as the possibility of ‘jumping the queue’ to get access to subsidised housing. As a consequence of its emergence, Plastic View has started placing press disturbances of its own on the surrounding community; property prices have become fragile (Issue 4), perceptions that crime in the area emanates from the informal settlement (Issue 5), and the increasing pollution and degradation of the city-scale watercourses and their biodiversity (Issue 6).
The ripple effects of built up press issues are felt up to the city-region scale. Tension in the surrounding community has led the council to disrupt Plastic View on a few occasions through attempted land evictions (Issue 10). However, eviction policy (Issue 3) and the assistance of local NGO’s protecting and supporting the settlers (Issue 11), has meant that there has been little change to the growth and longevity of the informal settlement. Natural disasters like seasonal flooding and fires (Issues 7 & 8) have not collapsed the settlement. Instead, they emphasise the connection to issues 1-3; since estate typologies and the commercial boom resulted in developments with expanses of hard surfaces, increasing storm water runoff and putting pressure on natural streams and storm water systems.

As press and pulse disturbances continue to impact on the panarchy, a recent pulse disturbance may have the greatest effect on the focal system. The recent court decision to formalise Plastic View (Issue 9) and permanently locate its legal residents in the area, sets a precedent for other similar instances of informality in the city (Issue 12). This will also have consequences for Issues 1-3: a) it will be an opportunity to integrate lost spaces in the disjointed city (Issue 1), by locating marginal workers closer to places of employment and spatially stitching communities together; b) it offers the poor alternatives to housing close to where they need to be to generate livelihoods (Issue 2) and c), it offers an opportunity to revisit current policy and find innovative ways to build adaptability and resilience into planning strategy (Issue 3). Issue 9 also affects the Plastic View community. It offers an opportunity to build resilience against natural disasters by applying methods that integrate natural processes and alternative planning, and also to build social resilience, strengthening the quality of educational, health, food security and recreational amenities for the informal settlement. Lastly, pulse Issue 9 has consequences for surrounding neighbourhoods; it offers the certainty of a workforce close to home and the possibility to build symbiotic networks of livelihoods that not only benefit the marginal workers in the informal settlement, but also most of the neighbourhoods around it.

Narrating these multi-scale relationships has highlighted the interconnectivity of disturbances in the panarchy and offers insight into understanding that as a system most events have an effect on the system as a whole, whether over a long period or suddenly, and that this effect filters through to other scales of the system (Capra, 1996). Further investigation of these relationships may enrich the research into mapping urban resilience of the City of Tshwane and may highlight that a necessary change is required in the way we think about development and planning for the future of South African cities. It shows that professionals, practitioners, academics and government officials involved in the built environment, need to rethink how we view change in urban systems (Wilkinson, Porter, & Colding, 2010) and identify potential therein for positive growth of urban systems in aspirational cities.

4. Conclusion

Having looked at the systemic pressures affecting the Tshwane city panarchy, from the perspective of an informal settlement called Plastic View, the understanding gained has shown that not only are the pressures exerted on the system multi-scaled, but also highly interconnected and interrelated. This understanding has led to the conclusion that current models of development are insufficient in dealing with press disturbances placed on
transitioning urban systems in South Africa while trying to cater for the demands of an increasingly Afropolitan society. This stems from lack of awareness about the interplay between press and pulse disturbances and their effects in the city. This understanding could assist in building resilience across the panarchy. Plastic View has demonstrated high levels of internal resilience while the surrounding neighbourhoods demonstrated weaker levels of resilience, partly due the uncertainty regarding the future of Plastic View. However, given the recent court decision to make it permanent, the integration of a lower income settlement close to wealthy suburbs may build diversity and capacity for overall system resilience, because its cross-scale networks are strengthened. This perspective offers an adaptable, dynamic and robust approach for assimilating changes into regenerative processes in the urban social-ecological system. Systemic change cannot be viewed as a linear concept, but rather as a dynamic framework (Wilkinson, Porter, & Colding, 2010) of interconnected and interdependent processes that collectively increase or decrease resilience.

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