The role of hospital infrastructure in building healthcare system resilience to extreme weather events in Australia

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Abstract

Extreme weather events can pose extraordinary risks for hospital infrastructure and by extension to community health and well-being. Not only can extreme weather events cause physical damage to hospital infrastructure but they can challenge the design capacity of hospitals by changes in the level and types of admissions. To explore the role that built assets play in their current disaster planning strategies a detailed analysis of twenty one (21) databases and a thematic content analysis of fourteen Australian hospitals disaster plan and supplementary plans is presented. Using Holling's adaptive cycle and Nonaka and Takeuchi's knowledge creation SECI model a Hospital Resilience Learning Cycle (HRLC) framework is developed which can help hospital stakeholders adapt their built environment to changing healthcare needs during EWEs.

Keywords: Extreme weather events, resilience, built environment, hospitals, thematic content analysis

1. Introduction

Extreme weather events (EWEs) are those that "exceed a particular threshold and deviate significantly from mean climate conditions" (Linnenluecke and Griffiths, 2010). Evidence indicates that many hospitals are vulnerable to such events. For instance some hospitals were completely destroyed during 2004 Hurricane Katrina in the USA (Rodriguez and Aguirre, 2006). Likewise in Australia many hospitals have been damaged and cut-off from surrounding communities during recent severe cyclones, storms and major flooding events in the last five years (Hunter New England, 2007, O'Brien, 2009, Schulenberg, 2009). Given that EWEs have the potential to impact significantly on community health and well-being, there is an urgent need for research into the factors that determine hospital resilience to such events. Given that building users in the health sector are largely unaware of the influence which buildings have on their day-to-day activities (Zimering et al 2005), the aim of this paper is to explore the importance that is given to built infrastructure in the development of disaster management plans in the health sector.

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2. Reconceptualising resilient hospital infrastructure

The concept of resilience is not new and emerged in the 1960s along with the rise of systems thinking. Resilience refers to a system's ability to react and respond to shocks and return to a previous stable state (engineering resilience) or to new future improved state (ecological resilience) (O'Rourke, 2007, Holling, 2001, Gunderson and Holling, 2002). A greater understanding of human and environment interactions that influence system resilience has in recent years led to a hybrid concept of socio-ecological resilience which is based on the human capacity to learn, innovate and adapt their behaviour to enhance a system's resilience. To explain this process, Gunderson and Holling (2002) developed the adaptive cycle (Figure 1) which involves four continuous phases of exploitation, conservation, release and reorganization. Exploitation (r) refers to the mature or stable state which tends to develop in systems as they exploit resources around them. Over time, the system accumulates and conserves resources (K) which are then released when faced with a disturbance (Ω). As the new disturbance abates, the system begins to reorganize (α) renew itself and eventually enter the exploitation phase once again.

The model of the adaptive cycle was derived from the comparative study of the dynamics of ecosystems. However, it can also provide new insights into how hospitals can become resilient to EWEs. For example, hospitals like all organisations become stable over time and develop organisational routines. They accumulate resources and build-up redundancies which are then used to cope with the extra demands imposed by an EWE. After the EWE event, the system then reorganises itself by learning lessons from how it coped with the EWE and incorporating these into new disaster policies and plans. Through this process the hospital enters a new state of improved resilience and equilibrium until a new EWE event throws it into the same cycle. Over time, as the hospital faces more EWEs, the hospital system strengthens its resilience to such events although never becomes perfectly resilient since the nature of these events are constantly changing. This of course is the theory. In practice the process is not likely to work as perfectly as described here.

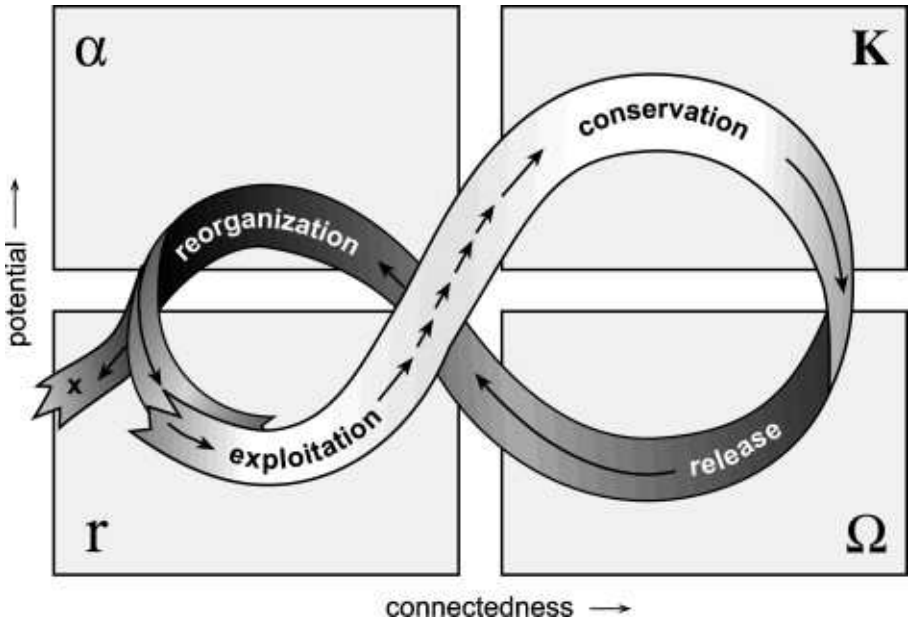

Figure 1: The adaptive cycle (Source: Gunderson and Holling 2002)

Central to the effectiveness of the adaptive cycle is the learning that occurs from each disturbance. However, the process is learning is not explained by the adaptive cycle. Nonaka and Takeuchi's (1995) model of organisational knowledge creation (SECI Model) helps to explain the process of organisational learning in more detail (Figure 2).

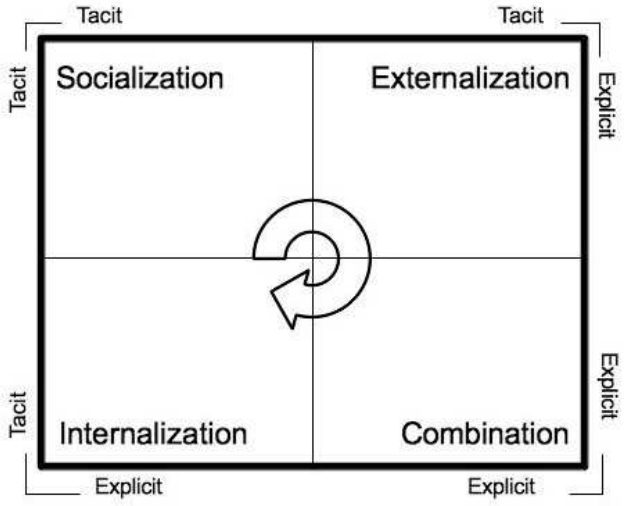

Figure 2: The SECI model (Source: Nonaka and Takeuchi 1995)

In Figure 2, socialisation is the process by which organisational members share tacit knowledge. By doing so they learn the norms and values of the organisation so that, they become part of that organisation's culture. This involves the sharing of feelings, emotions and experiences which allows people to break down interpersonal barriers and "get to know each other". In responding to an EWE this process is very important since people often have to move outside formal procedures to cope with unexpected situations. It also recognises the importance of understanding the needs and issues from individual hospital stakeholders perspective. Externalisation is the process of articulating tacit knowledge as explicit knowledge in the formulation of disaster management procedures which attempt to document how people should behave during an EWE. Combination is the process of connecting discrete elements of explicit knowledge (perhaps relating to different parts of the organisation) into an integrated disaster management plan which recognises that different parts of an organisation perform specific but interdependent functions during an EWE. In the context of responding to EWE's, this process might also involve the formulation of disaster management plans and policies which attempt to resolve conflicting interests and document how people from different parts of the organisation and external agencies should coordinate and interact during an EWE. For instance disaster planners and facility managers working together to inform appropriate disaster response and adaptation actions in the face of EWEs. Finally, internalisation is the process of embodying explicit knowledge as tacit knowledge, and when this happens, individuals'/organisation's existing tacit knowledge is broadened, extended, and reframed. This is the stage where a shared mental model is achieved so that

stakeholders respond automatically and instinctively during an EWE rather than having to resort to reading the rules and procedures and thus delay the response. This may be achieved through educational processes, repeated disaster drills, and scenario analysis. When this embodied tacit knowledge is shared with other individuals it creates a culture of resilience and sets off a new spiral of knowledge creation through socialisation etc.

Combining resilience theory with learning theory it is possible to propose a new conceptual framework called the Hospital Resilience Learning Cycle (HRLC) (Figure 3).

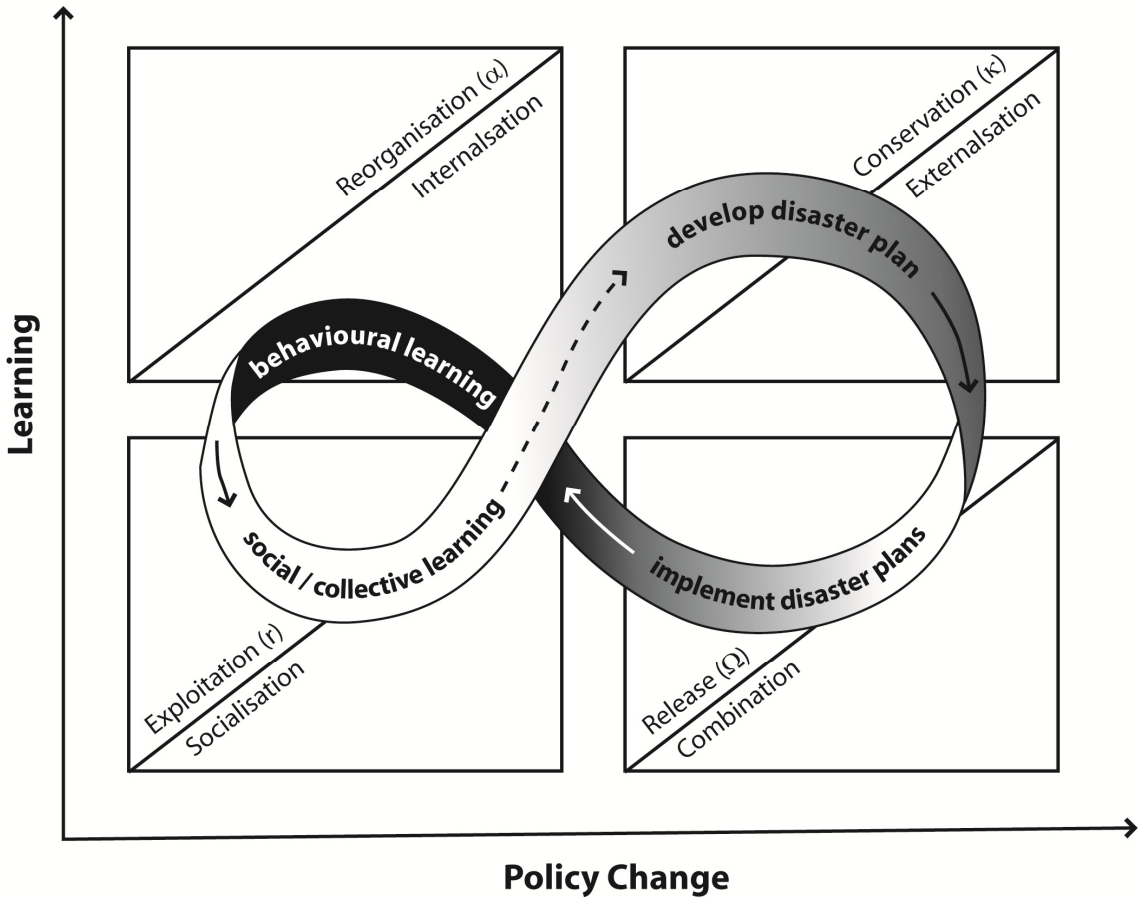

Figure 3: Hospital Resilience Learning Cycle (HRLC) (source: Chand and Loosemore 2012)

The HRLC model illustrates that the process of learning and adaptation are inextricably linked in the process of building organisational resilience to EWEs. It consists of four phases where the four phases of the adaptive cycle are combined with the SECI model. To interpret the HRLC model practically, the cycle begins with phase one: develop disaster plan.

Phase 1 (Develop Disaster Plans), is the conservation phase of the adaptive cycle where the hospital develops an organisational memory in the form of disaster management plans. This phase relates to the externalisation phase of the SECI model where tacit knowledge is made

explicit and recorded in the form of written procedures such as disaster plans. During the development of disaster plans as the new knowledge accumulates better understanding and agreement, it increases conformity and harmony amongst the hospital stakeholders. As a result disaster planning process can become rigid. For instance, emerging challenges such as the uncertain scenarios of EWEs are either ignored or not considered important. This increases the chance for disaster plans to fail or not being able to deal with new challenges during a new non routine EWE that is not accommodated in the Disaster Management Plans (DMPs).

Phase 2 *(*Implement Disaster Management Plans) is the release phase of adaptive cycle where stored resources in phase one are released. This relates to the deployment of resources through the implementation or activation of disaster plans developed in the conservation phase to deal with an EWE. It also relates to the combination phase of the SECI model since it involves integrating individual expertise from different parts of the organisation that are required to work together to collectively deal with an EWE. The effectiveness of hospital disaster plans and their preparedness to disasters are tested during this phase and provide the foundation for fundamental lessons in the next phase of the HRLC model.

Phase 3 (Behavioural learning) is equivalent to the reorganisation phase in the adaptive cycle and the internalisation phase in the SECI model where both these phases signify the generation of new knowledge and learning. The reorganisation phase indicates the re-structuring of the organisation post disaster as the lessons learnt from the implementation phase are absorbed. In the context of responding to EWEs, this can be related to behavioural learning amongst individual hospital stakeholders which is critical for re-organisation. Behavioural learning can results from both failure and success of disaster plans to deal with disaster impacts. People learn individually and also learn from each other. These lessons learnt from past experience are then internalised to broaden individual tacit knowledge that provide new insights for future disaster planning and thus relates to the internalisation phase of the SECI model.

Phase 4 (Social and collective learning) is the exploitation phase in the adaptive cycle where there is a rapid accumulation of resources such as new tacit knowledge. For instance, hospital stakeholders involved in a disaster response, come together and share their experiences. This sharing of individual tacit knowledge relates to the socialisation phase of the SECI model. This accumulation of tacit knowledge is converted to explicit knowledge in the form of changes in the existing policy or development of new policy in the first phase of the HRLC model (develop disaster plans) which continues the on-going adaptation over the life of a hospital to maintain its resilience.

3. Method

It is not possible within the confined of this paper to explore the entire HRCL model. For this reason we focus on phase one (Develop Disaster plans) where a hospital learns its lessons from previous EWEs and incorporates them into future disaster management plans. To investigate how this occurs in reality we undertook a thematic content analysis of disaster

plans and supporting supplementary plans across thirteen major hospital facilities in New South Wales (NSW). Supplementary Plans mainly included Critical Operations Standard Operating Procedures (COSOPS) and Business Continuity Plans (BCPs). The hospitals in our sample (Table 1) were selected on the basis of that they had been affected by EWEs in the recent past and therefore, theoretically at least, should have learnt from those experiences and incorporated these lessons into their disaster management plans. Another criterion for the sample selection was the significance of the hospital's service delivery in its local area during disasters. For instance, the hospital is used as a referral facility during disasters.

Table 1: Sample structure and descriptions

Hospitals	Description
A	**200 beds, major forensic facility in NSW, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
B	**50 beds, district hospital service and an extensive range of health services, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
C	**200 beds, Major hospital facility, service a population of 750,000. Sustained major damages to facility during 1999 hailstorm and minor damages in 2006**
D	**50 beds, hospital, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
E	**200 beds, Major hospital facility, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
F	**200 beds, hospital contains major training institute, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
G	**26 beds and 19 age care beds, district hospital service and an extensive range of health services, such as age care, affected by regular bush fires, floods in 2009, 2010 and 2011 and extreme heat in 2011**
H	**100 beds, district hospital service and has a range of allied health services, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
I	**88 beds and serves a population of 20,131, major hospitals. affected by regular bush fires, floods in 2009, 2010 and 2011 and extreme heat in 2011**
J	**50 beds, hospital, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
K	**35 beds, important regional multipurpose service facility with age care and respite care subsidy, major impact of their service delivery during 2009 dust storm**
L	**600 bed, major hospital contains 3 children's hospitals, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
M	**150 beds, main hospital for the population of Lake Macquarie, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**

The framework for analysing the hospital disaster plans and supplementary documents was based on Markus's BPRU model (Markus et al., 1972). According to Markus et al, a building facility and its stakeholders can be seen as an 'adaptive system' which comprises five key elements (sub-systems): the building system; the environmental system; the activity system; the objectives system and the resources system. The Building System comprises the external envelope; the structure; the division of internal spaces, services and contents. The Environmental System refers to the internal building environment created by the building system. The Activity System represents what happens within the facility and the Resources

System represents the external environment from which the other sub systems draw to enable them to function effectively. This includes the supply of physical, financial and human resources. The first four systems determined the coding themes for thematic content analysis. The disaster plans were examined using *NVivo*, the content analysis software. The use of this content analysis software allowed a thorough analysis of each document enabling frequency count of particular words and provided analysis of surface (manifest) and underlying (latent) meanings (Babbie, 2007). The content analysis software allowed searching for the synonyms and stemmed words of the individual variable of interest. The findings of the analysis are discussed below. Table 2 below presents the coding framework used for thematic content analysis.

Table 2: Content Analysis coding framework

Themes	Variables
Building	Building, window, fire alarm, lifts, stairs, roof, access, door, room, façade, structure/structural damage, Water, power/electricity, generator, light, air conditioning, phone line /telecomm, sewerage, equipment
Environment	Corridor, ventilation, heat, cold, humidity, lighting, air quality, temperature, air flow, smoke, infection control
Activity	Training, drill, staff, evacuation, transport, maintenance, repair communication, retrofit
Objective	Plan/Planning, debriefing, Service continuity, Business continuity, preparedness, patient treatment, emergency supplies

4. Results

Figure 4 presents the percentage of coded variables for all four themes in Markus's BPRU model.

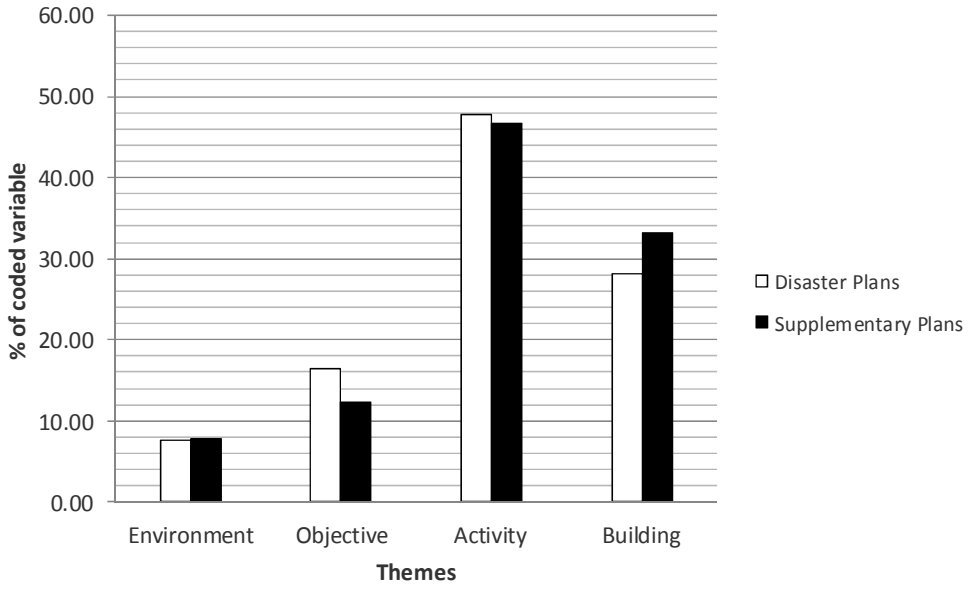

Figure 4: Percentage of coded variables

The BPRU model indicates that the four systems are equally important in delivering the organisational goals such as hospital service delivery and ensuring their facility resilience to EWEs. However, the variation across the four themes indicates that each hospital disaster plan is developed with consideration of their special issues. It is interesting to note that the internal environment that supports hospital service delivery has largely been ignored. Reflecting using the HRLC model, it can be associated with the lesson learnt from each hospital's past experiences. For instance, either their internal environment was not affect during the past events so the hospitals are less concerned about it or the disaster planners failed to internalise all the lesson learnt from the ground floor staffs across the hospital.

The low focus on objective theme which relates to governance issues to sustain hospital service delivery indicates that the hospitals are less concerned about the actual disaster planning process but more focused on the disaster response activities and building related issues. The HRLC model recognise the significance of governance structures that are comprised of the shared reasoning and decision making amongst the range of hospitals stakeholders involved in disaster planning, the adaptation process and the policies such as the disaster management plans that provide directions for hospital disaster preparedness and response.

The high focus on activity issues relates to both disaster preparation actions and response activities to ensure safety of staffs and patients during and after an event. For example, evacuation and transfer of patients to another facility, staffing issue, communicating with the external agencies that include police, ambulance, service utilities, roads authorities as well as conducting maintenance and repair activities. It is important to note that hospital service delivery is critically dependent on various external factors such as linen supply, medical supplies, fuel for backup generators, food supply, roads and utilities services such as power, water, sewage and communication. Thus, from the high focus on activity theme, it is can be assumed that the sample hospitals are well aware and able to deal with these activities in their plans. It can also be assumed that hospitals operational capacity to deal with EWEs is high and thus contribute toward the overall facility resilience.

Lastly, the building theme focus is relatively high as well which can be credited to the impacts of recent events on hospital infrastructure generating greater awareness and concerns regarding the building vulnerabilities. To determine the level of focus across the fourteen sample hospitals, the coded variables were plotted in figure 5.

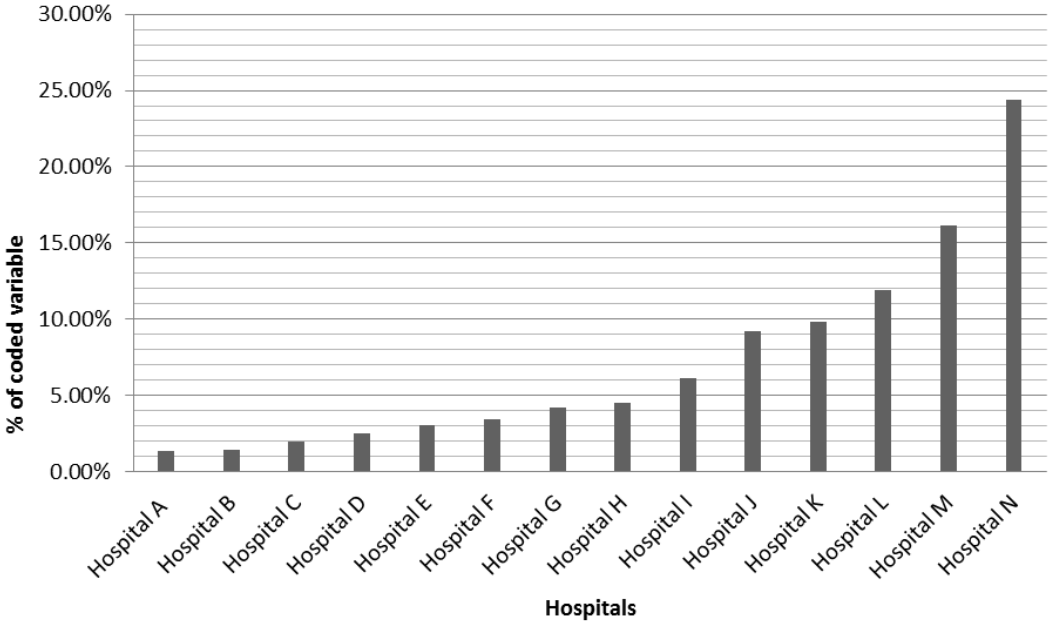

Figure 5: Percentage of coded variables for building theme for hospitals

Despite using a state template for both plans the variation on the level of focus on the building theme across the fourteen hospitals reveals the variation in hospital priorities. For instance, each hospital has its distinct issues due to their geographical locals, demography, and age of the facility. Additionally, it can be assumed that each hospitals level of focus is influenced by their past experiences. Alternatively, it can also be assumed that hospitals with low focus consider their built infrastructure is highly resilient to EWEs and thus ignore the link between their facilities and their healthcare activities. However, the purpose of this thematic analysis was to determine the focus on built infrastructure issue in the disaster plan, which is only part of the building theme. The building theme consists of service issues, content issues and construction related issued according to the BPRU model. As such, further breakdown of the building theme was carried out to identify the actually focus on building fabric issues. Table 4 shows the breakdown of focus on building theme particularly on building fabric issues in both plans.

Table 4: Focus on building fabric in the plans

Disaster Plans	**Supplementary Plans**
28% of disaster plans focused on Building theme	33% of supplementary plans focused on Building themes
11.76% of disaster plans focused on construction subtheme (which is 42% of building theme)	5.61% of supplementary plans focused on construction subtheme (which is 17% of building theme)
1.76% of disaster plans focused on hospital building fabric issues (which is 15% of construction sub theme)	0.29% of supplementary plans focused on hospital building fabric issues (which is 5% of the construction sub theme)

While the overall focus on building theme in both plans was relatively high around thirty per cent, a further breakdown of the building theme revealed that in reality only approximately two per cent of the disaster plans and less than one per cent of the supplementary plans focused on built environment related issues. This finding is important as it reveals that the actual focus on built environment issues in both plans is limited. Thus, it can be assumed that either hospital consider that their built facility is resilient to EWEs or fail to see the significance of the building fabric in their day to day hospital service delivery and during disasters.

Hospital facility resilience to disasters is dependent on a number of factors such as the hospital's organisational capabilities to learn from their past experiences and develop appropriate policies in consultation with the range of stakeholders identified earlier (Amaratunga et al., 2008). The robustness of the building fabric and its related services and content also contribute toward hospital facility resilience (Cimellaro et al., 2010). Additionally, the overall community resilience is also critical for hospital facility resilience. For example, the resilience of the hospital interdependent agencies such as age care and other healthcare facilities in dealing with EWEs issues, service utilities resilience, individual resilience of people in the community including hospital staffs and community patients (Loosemore et al., 2012). All these issues are represented by the four systems (building, environment, activity and objective) of the BPRU model. Thus, we argue that understanding the relationship between these four systems can promote hospital facility resilience. Alternatively, the HRLC model demonstrates that learning from past experiences is crucial for future planning. The findings of this thematic content analysis are significant in drawing more attention towards holistic planning in hospitals in promoting their facility resilience to EWEs.

5. Conclusion

The aim of this paper has been to present a conceptual framework, based on resilience and learning theories, that indicates how hospital stakeholders learn and adapt their built environment to EWEs. The limited focus on the building fabric in our hospitals indicates that despite a close link between the quality of healthcare delivered to communities and the quality of built infrastructure, low priority is given to built infrastructure issues in disaster responses, compared to the activities that happen inside those hospitals. This indicates a widespread assumption that the hospital built infrastructure is highly resilient to EWEs and an ignorance of the relationship between hospital facilities and the healthcare activities that go on inside them. Clearly the first assumption is wrong and the second finding reinforces the health facilities management literature which has consistently found over a long period that hospital are the forgotten resource in the health care system.

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