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Abstract

Purpose – The purpose of this paper is to explore the extent to which hospital disaster planners and managers understand the role of built infrastructure in delivering effective healthcare services during extreme weather events (EWEs). There is substantial evidence to indicate that many hospitals are vulnerable to EWEs. This is alarming given community reliance on hospitals during times of natural disaster and the predicted increase in the frequency and intensity of EWEs.

Design/methodology/approach – In this paper, resilience and learning theories are combined to produce a new conceptual model which illustrates how hospital disaster managers learn about the relationship between health outcomes and built infrastructure during EWEs to build future hospital resilience. In this paper, the first part of the conceptual model, concerning the development of disaster management plans is explored and refined using a thematic content analysis of 14 Australian hospitals' disaster plans and supplementary plans.

Findings – The findings indicate high variability of understanding about the role of built facilities in health outcomes during an EWE. There appears to be a widespread and highly questionable assumption in the health disaster planning community that hospital built infrastructure is highly resilient to EWEs. This means that many hospitals will not be unaware of the risks that their buildings pose in the delivery of healthcare services to the community during an EWE and how to manage those risks effectively.

Research limitations/implications – The theoretical framework presented in this paper provides new insights which will enable hospital infrastructure resilience to be better integrated into health service disaster risk planning and preparedness. The findings can help hospital disaster managers learn about and adapt their built environment to changing healthcare needs during EWEs.

Originality/value – By integrating learning and resilience theories in a built environment context, this paper provides new insights, both theoretical and practical, into the important role of hospital infrastructure in planning for EWEs.

Keywords Hospitals, Learning, Resilience, Disaster management, Built environment, Extreme weather events

Paper type Research paper

Introduction

Extreme weather events (EWEs) are caused by an individual climate variable such as temperature or rainfall that "exceeds a particular threshold and deviates significantly from mean climate conditions or when there is a critical combination of different variables" (Linnenluecke and Griffiths, 2010, p. 2). The increasing impact of EWEs on critical infrastructure such as roads, water and power supplies is well documented (Field *et al.*, 2012). The impact of hospital infrastructure is less well understood (Loosemore *et al.*, 2012),

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and the recent EWE experiences around the world highlight their vulnerability to such events. For instance, some hospitals were completely destroyed during 2004 Hurricane Katrina in the USA (Rodriguez and Aguirre, 2006) and in Australia many hospitals have been damaged and cut-off from surrounding communities during severe cyclones, storms and major flooding events in the recent past (Hunter New England Health, 2007; O'Brien, 2009; Schulenberg, 2009). Research shows that these vulnerabilities arose from many design-related and organisational factors and were exacerbated by the complexity of hospital operations, the large number of stakeholders involved and the interdependency of hospitals with external emergency services such as the emergency services (Achour and Price, 2010; McGeorge *et al.*, 2011).

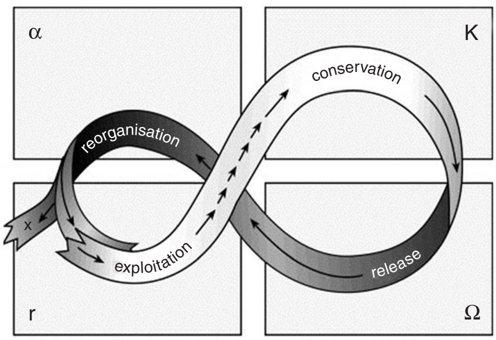
Given the importance and vulnerability of hospitals to the delivery of effective healthcare during disasters, there is an urgent need for research into the factors that determine hospital resilience to EWEs. To this end, an accumulating body of research is emerging around the physical and organisational determinants of resilience in the health sector (Bruneau and Reinhorn, 2007; Cimellaro *et al.*, 2010; Loosemore *et al.*, 2011). However, the important behavioural dimension of how hospital staff interact with their built environment and learn from this interaction has been neglected and is a clear gap in research which needs to be addressed. In other words, despite the critical importance of health infrastructure in responding to EWEs, we have very little insight into how much its users understand how to effectively use and/or adapt it in the face of such events. However, we do know that according to Zimring *et al.* (2005), many building users are unaware of the influence which buildings have on their day-to-day activities. The aim of this paper is to answer the question of whether this is also true in the health sector in relation to EWEs. More specifically, the aim of the paper is to use theories of learning and resilience to explore how hospital disaster managers learn from past EWEs to improve hospital resilience to future EWEs. Extending Zimring *et al.*'s (2005) research in the field of design, the hypothesis is that this process of building hospital infrastructure resilience is inhibited by barriers to learning from past EWEs.

Reconceptualising resilient hospital infrastructure

There has been a considerable amount of health facility-related research into how hospitals manage the risks of EWEs. For example, Carthey *et al.* (2008) assessed the adaptive capacity of hospitals to cope with EWEs, Chow *et al.* (2012) used a systems dynamics approach to model the impact of EWEs on hospital facilities, while McGeorge *et al.* (2011) used rich picture diagrams to do the same. Loosemore *et al.* (2010, 2014) explored EWEs from a hospital risk management perspective and Loosemore *et al.* (2013) explored the inter-agency risks of managing a hospital response to an EWE in Australia. Research on organisational learning in hospitals and on hospital resilience has also been undertaken. For example, Chandra and Loosemore (2010, 2011) explored the process of cultural learning during the briefing of hospital projects using cognitive mapping methods, although not in an EWE context. Achour and Price (2010) explored healthcare resilience strategies in two major hospitals in the UK and Taiwan using semi-structured interviews with emergency officers to clarify the strategies setup to respond to emergencies. Their findings showed that despite the robust emergency planning, many problems arose due to the failure of not working closer with multi-disciplinary experts, who provide technical and tactical help and lessons learned from international best practices. The study also suggested that climate change must be addressed comprehensively through fusing resilience and sustainability strategies into a more comprehensive strategy of adaptation. However, while it is clear that both learning and resilience theories can provide important new insights into the management of health facilities in high risk contexts, no research has as yet sought to integrate these theories in conceptualising and understanding how hospitals can better support healthcare outcomes during EWEs.

Resilience is commonly associated with the dynamic nature of the system's ability to react and respond to shocks (Gunderson and Holling, 2002; Holling, 2001; O'Rourke, 2007). However, Holling's (1973) seminal paper made an important distinction between engineering and ecological resilience. Holling defined engineering resilience as the ability of a system to return to an equilibrium or steady-state after a disturbance. In simple terms, more resilient systems bounce back faster. In contrast, ecological resilience was defined as the magnitude of disturbance that can be absorbed before the system changes its structure in order to remain within critical thresholds (such as certain standards of healthcare delivery to the community). As Davoudi (2012) points out, ecological resilience differs from engineering resilience in that it rejects the existence of a single state equilibrium. Instead it acknowledges the existence of multiple equilibriums and the tendency for systems to "flip" into alternative stability domains. In the natural world, an example of this would be a rainforest becoming a desert due to changes in climate. Despite this difference and the fact that they are rooted in different disciplinary traditions, what underpins both perspectives is the belief in the existence of equilibrium in systems, be it a pre-existing one which a resilient system bounces back to (engineering) or a new one which it transforms into (ecological).

Since Holling's formative work, the concept of resilience has generated much interest in the field of disaster management. For example, in economics the concept of resilience has been used to describe the economy's ability to recover from and adjust to disasters (Briguglio *et al.*, 2006). Other applications of the concept include organisational resilience (Warren, 2010), infrastructure resilience (Bruneau *et al.*, 2003), and institutional resilience (Aguirre *et al.*, 2005; Carthey *et al.*, 2001). Greater understanding of human and environmental interactions has also led to the hybrid concept of socio-ecological resilience. Socio-ecological resilience is based on the idea that systems never settle at equilibrium, but are in a constant state of adaptation and flux which is determined by the human capacity to learn, innovate and adapt. In this branch of resilience thinking, the concept of the adaptive cycle has been developed around concepts of "system dynamics" to show how systems change over time (Folke *et al.*, 2002; Holling and Gunderson, 2002; Holling *et al.*, 2002). In this adaptive cycle (Figure 1) there are four phases that illustrate the continuous processes of rapid growth,



Source: Gunderson and Holling, 2002, p. 34

Figure 1.
The adaptive cycle

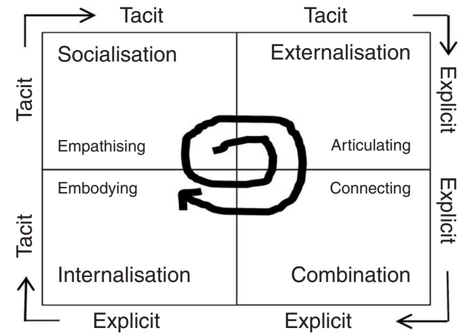
conservation, release and reorganisation of a system. Exploitation occurs (r) occurs following a recent disturbance as a system enters into a mature or stable state and conserves and accumulates resources (K) in preparation for the next inevitable shock. These stored resources (intellectual, social, financial, human, physical) are released to cope with the extra demands of a new disturbance (Ω), after which the system begins to reorganise (α) to suit its new environment with the newly available resources.

While useful as a model to explain how systems like hospitals adapt and respond to disasters, the adaptive cycle does not adequately explain how the learning underpins this process. To this end, Nonaka and Takeuchi's (1995) model of organisational knowledge creation (SECI Model) is useful. According to Nonaka and Takeuchi (1995) knowledge is created by a continuous and dynamic conversion of tacit and explicit knowledge (Figure 2). New knowledge starts with an individual who is the creator of knowledge, and then that individual's personal knowledge is transformed into organisational knowledge via a spiralling process which in turn gets transformed into concepts, models, artefacts and structures that define organisational behaviour. This knowledge creation process involves four stages of knowledge conversion, namely: socialisation, externalisation, combination and internalisation.

In Figure 2, socialisation is the process by which organisational members share tacit knowledge and learn the norms and values of the organisation to 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 during a crisis, people often have to move outside formal procedures to cope with unexpected situations (Loosemore, 2000). The process of socialisation is also useful in that it recognises the importance of collective understanding and norms in ensuring effective responses to EWEs.

Externalisation is the process of articulating tacit knowledge as explicit knowledge, and creating new, explicit concepts from tacit knowledge. When tacit knowledge is made explicit it becomes crystallised and its meaning for the organisation (in terms of its objectives) becomes apparent. In the context of responding to EWE's, this process is enshrined in the formulation of disaster management plans (DMPs) which attempt to document how people should 'behave' during an EWE.

Combination is the process of connecting discrete elements of explicit knowledge into an explicit knowledge set that is more complex and systematic than any of its parts. Combination can also include the "break-down" and recombination of concepts; for example, when middle managers analyse and break down organisational goals into



Source: Nonaka and Takeuchi, 1995

Figure 2.
The SECI knowledge conversion model

workable concepts. In the context of responding to EWE's, this process occurs when stakeholders from different parts of a hospital come together and interpret the formal DMPs in terms of how they should "coordinate and interact" during an EWE.

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 between all stakeholders involved in responding to an EWE. When this embodied tacit knowledge is shared with other individuals it sets off a new spiral of knowledge creation through socialisation, etc. In the context of responding to EWEs, this process may involve amendments to the disaster policy or procedure in responding to EWEs that is shared and accepted across the hospital.

The adaptive cycle and the SECI model focus on different aspects of the adaptive process, but combined they complement each other and represent a new conceptual framework to explore how hospitals adapt and respond to an EWE. This new framework is presented below and is called the Hospital Resilience Learning Cycle (HRLC).

The HRLC

A HRLC framework (Figure 3) integrates learning and resilience theories for the first time, providing new insights into the learning processes underpinning hospital responses to EWEs. Each phase of the HRLC model is described below in the context of hospital responses to EWEs.

Phase 1 (Develop disaster plan) is the conservation phase of the adaptive cycle where the hospital develops an organisational memory in the form of DMPs. This phase relates to the externalisation phase of the SECI model where tacit knowledge from stakeholders' experience of EWEs is made explicit and recorded in the form of written procedures such as disaster plans. As pointed out above, this includes plans relating to how the building will be managed, used and adapted during an EWE.

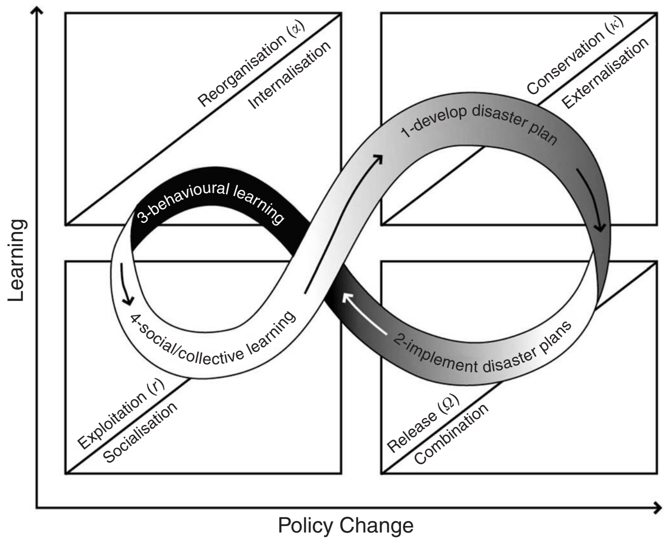


Figure 3. The Hospital Resilience Learning Cycle (HRLC)

Phase 2 (Implement disaster plan) relates to the release phase of the adaptive cycle and represents 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 which are required to work together to manage, use or adapt the building to collectively deal with an EWE.

Phase 3 (Behavioural learning) is equivalent to the reorganisation phase in the adaptive cycle and the internalisation phase in the SECI model. It involves the re-structuring of the organisation post disaster as the lessons learnt from the implementation phase are shared between the stakeholders (including those involved in managing, using and adapting the building) and absorbed to instinctively inform future responses.

Phase 4 (Social and collective learning) relates to the exploitation phase in the adaptive cycle and the socialisation phase in the SECI model. Here there is a rapid accumulation of new tacit knowledge as hospital stakeholders involved in a disaster response come together and share their experiences (including about how the building is managed, used and adapted). This accumulation of tacit knowledge is converted to explicit knowledge in the form of changes in the existing policy or development of new policies and plans in the first phase of the HRLC model (develop disaster plans) which continues the ongoing adaptation over the life of a hospital to maintain its resilience.

Methodology and method

The social process of learning and adaptation described in the HRLC model were explored using a constructionism ontology which implies that the construction of knowledge in hospitals is shaped by social processes and shared interactions amongst hospital stakeholders (David and Sutton, 2011). This in turn leads to an interpretive epistemology which recognises the need to use qualitative methods of data collection to identify the multiple social constructions of the phenomena of learning and adaptation during an EWE (Young and Collin, 2004).

This paper focuses on the initial phase of the HRLC model (develop disaster plans). This was explored using a thematic content analysis of disaster plans in 14 major hospital facilities in the State of New South Wales Australia to identify the extent to which built infrastructure considerations feature in those plans and how lessons learnt during past EWEs had been integrated into those plans.

The 14 hospitals in our sample are described in Table I. The hospitals were selected on the basis that they had been affected by EWEs in the recent past and that their disaster management team had the opportunity to have learnt from those experiences and incorporate these lessons into adapted DMPs. Another criterion for the sample selection was the significance of the hospital's service delivery in its local area during disasters.

Data were collected by a combination of documentary analysis and a focus group with a Disaster Management Committee. The documentary analysis provided insights into the formal instructions given the hospital disaster managers in responding to an EWE. Given that people during a disaster often do not have time to think, the instructions in disaster plans are highly important to the way they behave (Carley and Harrald, 1997, p. 117). It can therefore be assumed that failure to recognise built infrastructure issues in the disaster plans means that those issues will not be considered in the hospital's disaster response. The focus group was used as a "post-primary tool" to validate the research findings generated from other means as well as to

Hospitals	Description
A	150 beds, main hospital for the population of Lake Macquarie, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
B	35 beds, important regional multipurpose service facility with aged care and respite care subsidy, major impact on their service delivery during 2009 dust storm
C	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
D	200 beds, the hospital contain major training institute, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
E	50 beds, hospital, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
F	200 beds, major referral hospital for the region, suffers significant extreme weather events including floods (3×1 in a 100 year events alone in 2009) and storms (major 2007 hailstorm, 2008, 2013, 2015). These events damaged hospital building, infrastructure and vehicles as well as disrupted dependent services that disrupted hospital services
G	600 beds, major hospital contains 3 children's hospitals, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
H	50 beds, hospital, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
I	200 beds, Major hospital facility, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
J	200 beds, major forensic facility in NSW, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
K	50 beds, district hospital service and an extensive range of health services, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
L	26 beds and 19 aged 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
M	100 beds, district hospital service and has a range of allied health services, sustained damage to the hospital building, infrastructure and vehicles during 2007 severe weather
N	200 beds, major hospital facility, service a population of 750,000. Sustained major damages to facility during 1999 hailstorm and minor damages in 2006

Table I.
Sample structure and descriptions

generate new insights that can only be captured through the group interactions of these participants (David and Sutton, 2011, p. 134; Cronin, 2001). In addition, it also provided the opportunity to observe the group dynamics between the hospital stakeholders involved in disaster management planning.

In the documentary analysis 14 hospitals "disaster management plans" and "supplementary disaster plans" were analysed. Disaster plans are broad and generic documents that provide strategic directions and general details for disaster coordination, whereas supplementary plans focus on how individual activities and resources are used in responding to an EWE. In other words, the disaster plans focus on the "why" of responding to an EWE and the supplementary plans focus on the "how" of implementation. The focus group lasted about four hours and participants were the key hospital stakeholders involved in disaster planning who were experts in various healthcare fields (Table II).

The effectiveness of a focus group as a method data collection is subject to a well organised sample, well prepared guide and clear instructions for the participants to facilitate the discussion (Cronin, 2001; Goss and Leinbach, 1996). In this research, the complex multi-disciplinary nature of disaster responses to EWEs required participant diversity from various professional backgrounds to highlight the range of issues that

Table II.
Focus group participants

Focus group participant	
Executive managers	The network general manager/disaster controller Director of nursing Direction of allied services Director of clinical services
Senior manager	Hospital facility manager Hospital nurse manager Nurse unit manager for emergency department Quality manager Environmental manager OH and S manager
External stakeholder	Disaster network nurse consultant

might be faced (Morgan, 1997; Powell and Single, 1996). However, it was recognised that hospitals have a strong hierarchical structure based on a top-down command and control governance system which meant that staff lower in the hierarchy may be reluctant to contribute to the discussion. Another concern was that the group members may withhold sensitive information in such settings, thus weakening the depth validity of the data collected. Somekh and Lewin (2005) argued that every participant may have their own agenda for participating in the focus group and only press their particular concerns during the discussion. These issues were managed by experienced and independent facilitation which enabled all members to contribute equally. Furthermore, the focus group discussion was carefully structured with questions for discussion predetermined from the preliminary results of the documentary analysis. Another key to the effectiveness of the focus group is in the presentation of clear instructions about the purpose, process and the questions to be answered, to avoid confusion and maintain the flow of the discussion. However, too much information can also confuse the participants and discourage them from talking (David and Sutton, 2011). So to ensure the clarity and simplicity of the discussion process, a power point presentation was given at the start of the focus group with a series of key findings and questions for discussion which were systematically addressed in turn.

Data were analysed and coded using Markus's BPRU model which was developed to represent the link between building users and buildings (Markus *et al.*, 1972). Despite its age, the BPRU model remains the most comprehensive and tested conceptual framework for understanding the relationship between buildings and their users. It illustrates effectively how different elements of the "built environment system" relate to each other and therefore, provides a useful approach to examine hospital disaster preparation and response effort in a built environment context. According to Markus *et al.* (1972), a building facility and its stakeholders can be seen as an "adaptive system" which comprises five sub-systems: environmental sub-system; activity sub-system; building sub-system; objectives sub-system; and the resources sub-system. The "Building System" comprises the external envelope; the structure; the division of internal spaces, services and contents of a hospital. The "Environmental System" refers to the internal building environment created by the building system, such as the circulation space created by the corridors in a hospital ward. The "Objective System" refers to the reasons why the building exists (that all disaster patients are treated with good quality healthcare). The "Activity System" represents what happens within the facility which in the case of hospitals includes disaster response and recovery activities to sustain hospital services during an EWE as defined by the DMPs. The "Resources sub-system" represents the external environment from which the other sub-systems draw resources to function effectively. This includes the supply of medical, physical, financial and human resources. The environment, resources, objective and activity systems represent the organisational (soft infrastructure) and the building system represents the built component (hard infrastructure) of the hospital facility.

In analysing the DMPs of the 14 case study hospitals in our sample as described in Table I, four out of the five systems in the BPRU model were used as coding themes: the environmental system; the activity system; the building system; and the objective system. The fifth sub-system "resources" was not used as a coding theme because the focus of our research was on built infrastructure not external resource supply chains. In using Markus *et al.*'s (1972) model, Table III illustrates the coding framework employed the in the content analyse of our sample's DMPs. The building theme was further categorised into three sub-themes that include: construction, content and services (Table IV).

Discussion of results

Before progressing to discuss the results, it is important to note that this research took place in Australia, a context which may limit the generalisability of the findings to other contexts. First, Australia faces unique types of EWEs and related health implications which other countries might not face. The nature of these challenges impact directly on the types of lessons which hospitals in different countries would have to learn, even though the cognitive mechanisms by which this happens are universal. For example, Hughes and McMichael (2011) found that EWEs have potentially serious consequences for Australian's health. More frequent and intense heatwaves can result in more heart

Sub-system themes	Variables
Building	Building, window, fire alarm, lifts, stairs, roof, access, door, room, water, power/electricity, generator, lightening, air conditioning, phone line, sewerage, equipment, alarm, telecommunication
Environment	Circulation space, ventilation, heating, cooling
Activity	Training, drill, staff, evacuation, transport, maintenance, repair communication, retrofit
Objective	Plan/planning, debriefing, service continuity, business continuity, preparedness, patient treatment, emergency supplies

Table III. Content analysis coding framework

Building Sub-themes	Description	Variables
Construction	The external envelope; the structure; the division of internal spaces i.e. the building fabric	Building, window, lifts, stairs, roof, access, door, room
Content	Mechanical and electrical services providing air conditioning; lighting and power	Water, power/electricity, generator, lightening, air conditioning, phone line, sewerage
Services	Furniture and fittings – in a hospital context this would include surgical equipment; beds; diagnostic equipment, etc.	Equipment, alarm, telecommunication

Table IV. Building sub-themes

attacks, strokes, accidents, heat exhaustion and death. Storms, floods and cyclones can result in more injuries, deaths and post-traumatic stress. More fires from heatwaves can increase cases of smoke-induced asthma attacks, burns and death. Other less predictable health impacts from EWEs include more exposure to air pollutants and air-borne allergens, such as pollens and moulds, exacerbating respiratory illnesses, such as asthma, hay fever and longer term heart and lung diseases; increases in the spread and activity of disease transmitting mosquitoes and increasing the chances of food-borne infections; a higher prevalence of mental health problems and lower morale in rural communities; reduced supply and increased prices of some foods, resulting in reduced nutrition; displacement of people from within and outside of Australia and community-wide negative effects on social and economic wellbeing. All of these impacts they concluded will put increased pressure on health systems and emergency responses, delaying effective delivery of healthcare. While other countries around the world might face similar challenges, it is important to note that our results are presented in the context of these direct EWE threats. Furthermore, the way that Australian health professionals might react is likely to be influenced by the Federal system of government in Australia, where the central Federal Government requires individual states to develop their own DMPs. Individual hospital disaster planning in each state then falls under the State Health Plan and DMP. As Loosemore *et al.* (2013) found, this complex multi-layered governance structure presents uniquely overlapping structures and processes which might hinder learning about EWEs. Once again, this governance system differs in various parts of the world. The Federal Department of Health and Human Services in the USA oversee the national public health and medical emergencies through their national committees/ agencies such as the Federal Emergency Management Agency, frameworks (e.g. The National Response Framework) and programme (The National Healthcare Preparedness Programme). state, territory and local municipal hospital disaster preparedness comply with the national policies and response is escalated to Federal if the local/state disaster response resources are exhausted. The National Healthcare Preparedness Programme also provide grants and cooperative agreements between healthcare and emergency response bodies to form health coalitions and work collaboratively towards improving their capacities to deal with disasters (Federal Emergency Management Agency (FEMA), 2010; Office of the Assistant Secretary for preparedness and response (OASPR), 2012). In the UK, the Federal Department of Health is the lead agency for health emergencies that develops plans and policies and sets disaster response actions and activities across all jurisdictions (Department of Health UK, 2015).

Nevertheless, within this context Figure 4 presents the percentage of all coded variables (*x*-axis) for all four systems (*y*-axis) aggregated across all 14, phase one sample hospitals.

As illustrated in Figure 4, the focus of the sample hospitals' response to EWEs varied across the four coded systems. According to the BPRU Model, all four systems (environment, objective, activity and building), were equally important in the disaster and supplementary plans. However, the variation across the four systems in both disaster and supplementary plans indicated that their relative importance varied significantly in both types of plans. For example, according to Figure 4, the environment system appears to be seen as least important in the disaster and supplementary plans analysed. While we were not able to establish whether this was an appropriate level of priority or not (because an appropriate level is impossible to establish), this finding was surprising given the high sensitivity of healthcare delivery to the building's internal environment. For instance, any changes in the internal

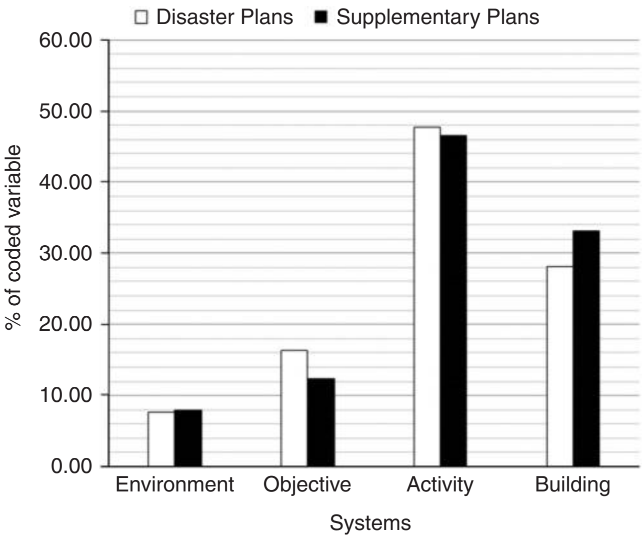


Figure 4.
Percentage of coded variables for all four systems across the sample hospitals

environment, such as a rise in temperature or the deterioration of the air quality, could significantly disrupt efficient patient care, particularly for patients suffering burns or chronic asthma. The internal environment could be particularly vulnerable to power outages that are quite common during EWEs such as heatwaves, which impose a surge in demand on the electricity grid system. See, for example, Hiete *et al.*'s (2011) scenario-based impact analysis of power outages on German healthcare facilities which shows the devastating impact power outages can have on hospitals.

This finding was further investigated in a focus group meeting, which supported the apparent disregard among hospital stakeholders' for their internal environment in the DMPs. Their explanation for omitting this system was that they did not have the resources to influence or modify the internal environment post construction:

> The other side of doing prevention of the building [integrity] actually requires investment and we [the hospitals] don't have control over those monies.

This lack of apparent control is significant given the relationship between internal environment and healthcare during an EWE.

Similarly, the relatively low focus on the objective system is explained by it being a low priority in the state government's template for disaster and supplementary plans. These templates were followed closely and the primary objective of the disaster and supplementary plans is considered to provide a detailed description of the actions related to disaster response and recovery to maintain services to the community. This finding was also supported by the focus group participants:

> We are human services, so our primary concern is going to be about people. We worry about the people and what we do about service delivery, as opposed to the building, and that's the focus, that's the primary focus because we are a core, critical service […]. Disaster plans are compiled by people from a services background who are primarily concerned with service related issues.

This is an interesting finding as the literature suggests that EWEs present hospitals with very different challenges compared to normal operations. There is significant evidence to indicate that objectives might need to change to deal with such an event. For example, by comparing the functioning of hospital networks before and after an EWE, Loosemore *et al.* (2012) show that there are many new risks which arise, for which hospitals are unprepared (such as dealing with an influx of elderly patients from local aged care facilities which cannot cope or accommodating staff that cannot leave due to flooding or security constraints). While we were not able to ascertain whether the amount of focus on the objective system was appropriate or not, this would suggest that a hospital needs to be able to ensure that its DMPs allow it to reconfigure its "normal" role during an EWE to consider these new roles and requirements of the surrounding community and healthcare system in which it is imbedded.

Finally, the relatively high focus on the activity and the building systems demonstrates that disaster and supplementary plans currently focus on service delivery and the awareness of how the physical hospital building is being used in responding to EWEs. In the context of our case study hospitals, the high focus on the building system could also be credited to the impacts of recent EWEs on hospital buildings in Australia, generating greater awareness of building vulnerabilities. According to the focus group participants, their past disaster experiences, the retention of their corporate knowledge and the post disaster debriefing activities, all increased their awareness of the building system when responding to EWEs:

> There's enough people around who have been here for the history of the building to be able to talk of those things, and in a disaster exercise there's always the debriefs.

Further analysis was undertaken to determine the level of focus on the four systems across the 14 sample hospitals (see Figure 5).

According to Figure 5, the percentage of coded variables for each system across the 14 hospitals varied greatly, despite the hospitals using the same state government

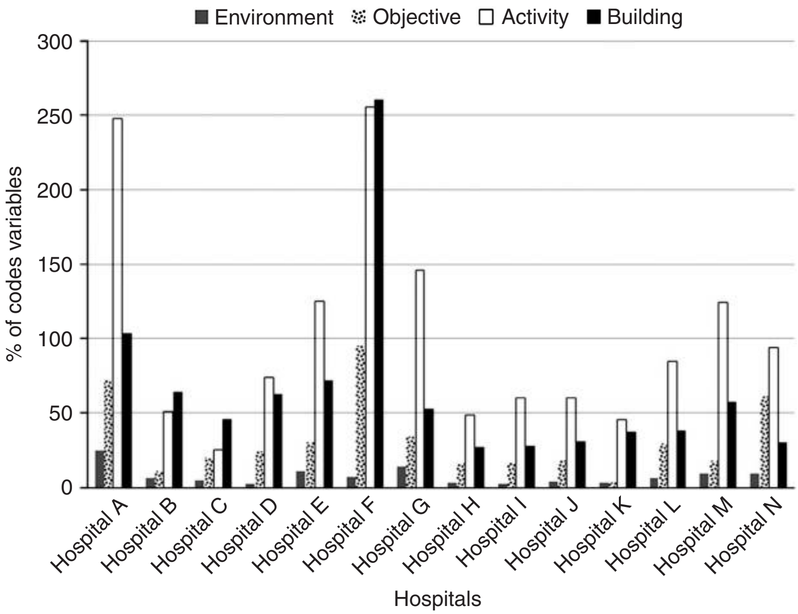


Figure 5.
Percentage of coded variable for all four systems across the sample hospitals

template for creating their disaster and supplementary plans. The variations indicate that hospitals' disaster and supplementary plans are developed with consideration for those circumstances unique to them. These variations illustrate that individual hospitals have very different understandings of the role of their built infrastructure in dealing with EWEs. In seeking to explore this further, focus group discussions indicated that the variation were likely to have been the result of different learnings and experiences in dealing with past EWEs. For example, where built infrastructure had been significantly affected by an EWE in the past (as in hospital F, which sustained roof damage and lost over 50 patients and staff cars in a recent flooding event), DMPs tended to reflect a realisation of the criticality of built infrastructure in protecting such assets. This is significant in that it suggests that learning about the role of built infrastructure in responding to EWE's primarily occurs through experience rather than any formally dictated guidelines. Emergency drills and other simulation exercises are therefore likely to be particularly important in bringing this learning about, although in reality it is very difficult to simulate the impact of an EWE on the fabric of a building or the surrounding infrastructure during a drill. Emergency drills are far more effective at replicating impacts on the objective and activity systems which perhaps explains their prominence in DMPs.

Focus group participants also emphasised that each hospital had its distinct disaster risks due to geographical locations, designs, demography and age of the hospital facility, which influenced the level of focus on the built infrastructure. Typically, the older hospitals tended to focus more on built infrastructure, presumably because their designs was more outdated and the built fabric in a higher state of deterioration.

The building system in the Markus's BPRU model consists of three components: content, services and construction. Table V presents the percentage of coded variables for the building system and the construction sub-system in both plans.

Table V demonstrates that despite a relatively high overall percentage of coded variables around (30 per cent) for the building system, only a small proportion of that relates to hard infrastructure, in both sets of plans. This finding demonstrates that while the hard infrastructure risks are identified in the disaster plans, the disaster response actions to deal with these risks are reduced in the supplementary plans. In contrast, the service component of the building theme is small in the disaster plans, but the disaster-related response actions substantially increase in the supplementary plans. This finding is consistent with disaster management research (Donohue *et al.*, 2010). According to Donohue *et al.* (2010), DMPs provide detailed planning for and responding to the disaster risks and their consequences, whereas, contingency planning indicated in the supplementary plans outline the specific managerial and technical actions and potential response to deal with an emergency situation.

Systems	Disaster plans (%)	Supplementary plans (%)
The building system	28	33
The construction sub-system	11	7
The content sub-system	14	15
The service sub-system	3	11

Note: Percentage of variables coded for the building system and the construction sub-system (hard infrastructure) in both the plans

Table V. Level of focus on building system and sub-systems in both plans

Interestingly, the largest portion of the building theme coded variables related to the content sub-theme in both the plans. This finding indicates that both plans place greater emphasis on supply services such as telecommunication, water, power and sewerage service rather than the risks associated with the hard infrastructure. According to the focus group participants, this high focus on content was due to the regular disruptions to their supply services during past EWEs (power outages are common during such events). It was also due to the high dependence of patients for life support on these services. The focus groups also highlighted hospital disaster planners' strict delineations in their responsibilities in providing health services did not require them to be aware of built infrastructure issues which they did not see as directly impinging on health service outcomes. According to the focus group participants, facilities managers responsible for built facilities were largely excluded from the DMP process and there was a widespread perception that the hospital facilities were "safe", as they are built in accordance with building codes and standards, particularly with regards to new facilities. However, as Carthey *et al.* (2009) point out, this assumption is flawed since there are many health facilities (even new facilities) in Australia which are not designed with EWE risks in mind and are in fact a risk rather than an asset to the continued delivery of healthcare services to the community during an EWE. The focus group discussions also revealed that building-related challenges were perceived to be the province of the general capital works maintenance plans, where it was assumed that planning for EWEs was occurring, when in fact it was not:

> We are health people and we know the health environment we know what's practical what's appropriate but equally you need to also be able to understand the [building design] plans. The [building related problems] get included as part of [the] works plan as opposed to disaster management.

These findings further demonstrate that the fragmentation and strict delineation of the actors and roles involved in the disaster planning process around built facilities ensures the exclusion of built facility considerations in both disaster and supplementary plans. The frequency of coded variables for the construction sub-system was also compared across the 14 sample hospitals (Figure 6) provides further insights into this problem.

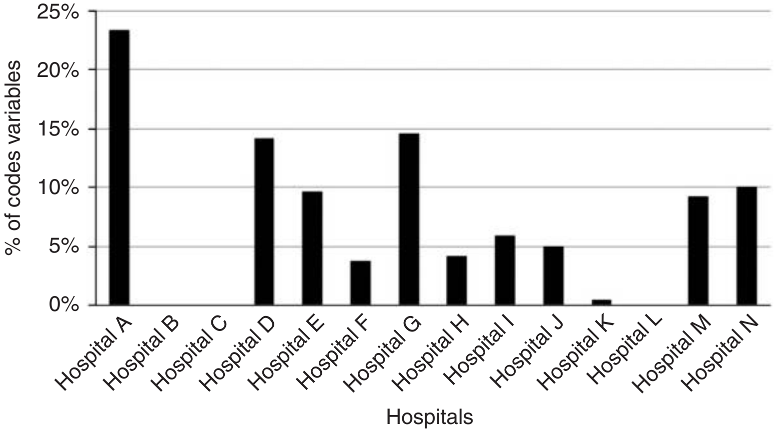


Figure 6.
Percentage of coded variable for construction sub-theme across the 14 sample hospitals

Figure 6 shows that the level of focus on the hard infrastructure also varied greatly across the sample hospitals. In fact, some of the sample hospitals did not have any reference to hard infrastructure in their disaster and supplementary plans which meant that in some hospitals in our sample there was little if any disaster planning for the built facilities taking place. The focus group participants explained that the inclusion of built facilities in disaster and supplementary plans are subject to a hospital's very specific circumstances and the lessons learnt from their lived historical experiences of dealing with EWEs. Similarly, the age of hospital building, the materials used for construction and the conditions under which the facility was constructed also influenced the focus on the building system. According to the focus group participants, an old hospital building with obvious signs of deterioration would generate more concern for the facility. Conversely, it is easier to ignore hard infrastructure issues if it is a relatively new building with no signs of ageing.

Conclusion

The aim of this paper was to explore the extent to which hospital stakeholders' appreciate the role of built infrastructure in delivering effective healthcare services to the community during EWEs. By integrating theories of learning and resilience for the first time, it presented a new conceptual model which was tested using documentary analysis of DMPs and a focus group with professionals involved in disaster management planning and response. The findings indicate that there is a highly variable focus on built facilities in current health DMPs in Australia. In some hospitals there is no detectable focus at all. They also highlight a widespread assumption in the health disaster planning community that hospital built infrastructure will be unaffected by the EWEs and is already resilient in responding and adapting to any challenges it may face. This complacency means that many hospitals will be unaware of the risks that their buildings pose to the delivery of healthcare services to the community during an EWE and how to manage those risks effectively when something goes wrong. Given ongoing research which continues to point to an increasing incidence of EWEs into the future, this is a worrying finding. It is particularly worrying given the accumulating research that also points to the vulnerability of hospitals, both new and old, to EWEs.

The practical implications of this research are significant. In particular, it indicates that there is a real need to develop better ways to simulate the impact of EWEs on the hospital fabric and its surrounding infrastructure. New visualisation and simulation technologies may be particularly powerful tools to do this and need to be explored as a learning mechanism in disaster management planning. Technologies better involve facilities managers in the disaster management planning process so that lessons learnt from observing the performance of built facilities during as EWE can be used to improve the resilience of existing and future hospital buildings into the future. The findings also indicate that there is also a need to better involve facilities managers in the disaster management planning process so that lessons learnt from observing the performance of built facilities during as EWE can be used to improve the resilience of existing and future hospital buildings into the future. The marginalisation of facilities managers in hospital organisations is a perennial problem which is supported here, and this research shows that the implications for hospital resilience are clearly significant.

References

Achour, N. and Price, A. (2010), "Resilience strategies of healthcare facilities: present and future", *International Journal of Disaster Resilience in the Built Environment*, Vol. 1 No. 3, pp. 264-276.

Aguirre, B., Dynes, R.R., Kendra, J. and Connell, R. (2005), "Institutional resilience and disaster planning for new hazards: insights from hospitals", *Journal of Homeland Security and Emergency Management*, Vol. 2, pp. 1-16.

Briguglio, L., Cordina, G., Farrugia, N. and Vella, S. (2006), "Conceptualisingand measuring economic resilience", in Briguglio, L. and Kisanga, E. (Eds), *Building the Economic Resilience of Small States, Malta: Islands and Small States Institute, of the University of Malta and London: Commonwealth Secretariat*, Formatek, London, pp. 265-288.

Bruneau, M. and Reinhorn, A. (2007), "Exploring the concept of seismic resilience for acute care facilities", *Earthquake Spectra*, Vol. 23 No. 1, pp. 41-62.

Bruneau, M., Chang, S.E., Eguchi, R.T., Lee, G.C., O'Rourke, T.D., Reinhorn, A.M., Shinozuka, M., Tierney, K., Wallace, W.A. and Von Winterfeldt, D. (2003), "A framework to quantitatively assess and enhance the seismic resilience of communities", *Earthquake Spectra*, Vol. 19 No. 4, pp. 733-752.

Carley, K.M. and Harrald, J.R. (1997), "Organizational learning under fire: theory and practice", *Crisis Management*, Vol. 40 No. 3, pp. 315-332.

Carthey, J., Chandra, V. and Loosemore, M. (2008), "Assessing the adaptive capacity of hospital facilities to cope with climate-related extreme weather events: a risk management approach", in Dainty, A. (Ed.), *Proceedings 24th Annual ARCOM Conference*, Vol. 2, Association of Researchers in Construction Management, Cardiff, pp. 1145-1154.

Carthey, J., Chandra, V. and Loosemore, M. (2009), "Adapting Australian health facilities to cope with climated related extreme weather events", *Journal of Facilities Management*, Vol. 1 No. 7, pp. 36-51.

Carthey, J., De Leval, M.R. and Reason, J.T. (2001), "Institutional resilience in healthcare systems", *Quality in Health Care*, Vol. 10 No. 1, pp. 29-32.

Chandra, V. and Loosemore, M. (2010), "Mapping stakeholders' cultural learning in the hospital briefing process", *Construction Management and Economics*, Vol. 28 No. 7, pp. 761-769.

Chandra, V. and Loosemore, M. (2011), "Communicating about organizational culture in the briefing process: case study of a hospital project", *Construction Management and Economics*, Vol. 29 No. 3, pp. 223-231.

Chow, V., Loosemore, M. and McDonnell, G. (2012), "Modelling the impact of extreme weather events on hospital facilities management using a system dynamics approach", in Smith, S.D. (Ed.), *Proceedings 28th Annual ARCOM Conference*, Association of Researchers in Construction Management, Edinburgh, pp. 1157-1166.

Cimellaro, G.P., Reinhorn, A.M. and Bruneau, M. (2010), "Seismic resilience of a hospital system", *Structure and Infrastructure Engineering*, Vol. 6 Nos 1-2, pp. 127-144.

Cronin, A. (2001), "Focus groups", in Gilbert, N. (Ed.), *Researching Social Life*, 2nd ed., Sage Publications, London, pp. 164-177.

David, M. and Sutton, C.D. (2011), *Social Research: An Introduction*, Sage, London.

Davoudi, S. (2012), "Resilience: a bridging concept or a dead end", *Planning Theory & Practice*, Vol. 13 No. 2, pp. 299-307.

Department of Health UK (2015), "Policy paper: 2010 to 2015 government policy: health emergency planning", available at: www.gov.uk/government/publications/2010-to-2015-government-policy-health-emergency-planning/2010-to-2015-government-policy-health-emergency-planning (accessed 23 October 2015).

Donohue, S., Masilele, T. and Gear, J. (2010), *Disaster Management*, Chapter 24, Health System Trust, available at: www.healthlink.org.za/uploads/files/chapter24_00.pdf (accessed 14 April 2015).

Federal Emergency Management Agency (FEMA) (2010), *Comprehensive Preparedness Guide 101: Developing and Maintaining Emergency Operations Plans – Version 2*, USA Department of Homeland Security, Washington, DC.

Field, C.B., Barros, V., Stocker, T.F., Dahe, Q., Dokken, D.J., Plattner, G.-K., Ebi, K.L., Allen, S.K., Mastrandrea, M.D., Tignor, M., Mach, K.J. and Midgley, P.M. (2012), Managing the risks of extreme events and disasters to advance climate change adaptation", New York patent application: a special report of the Intergovernmental Panel of Climate Change, Cambridge University Press.

Folke, C., Carpenter, S., Elmovist, T., Gunderson, L., Holling, C. and Walker, B. (2002), "Resilience and sustainable development: building adaptive capacity in a world of transformations", *AMBIO: A Journal of the Human Environment*, Vol. 31 No. 5, pp. 437-440.

Goss, J.D. and Leinbach, T.R. (1996), "Focus groups as alternative research practice", *Area*, Vol. 28 No. 2, pp. 115-123.

Gunderson, L. and Holling, C. (2002), *Panarchy Synopsis: Understanding Transformations in Human and Natural Systems*, Island Press, London.

Hiete, M., Merz, M. and Schultmann, F. (2011), "Scenario-based impact analysis of a power outage on healthcare facilities in Germany", *International Journal of Disaster Resilience in the Built Environment*, Vol. 2 No. 3, pp. 222-244.

Holling, C. (1973), "Resilience and stability of ecological systems", *Annual Review of Ecology and Systematics*, Vol. 4 No. 1, pp. 1-23.

Holling, C. (2001), "Understanding the complexity of economic, ecological, and social systems", *Ecosystems*, Vol. 4 No. 5, pp. 390-405.

Holling, C. and Gunderson, L. (2002), "Resilience and adaptive cycles", in Gunderson, L.H. and Holling, C.S. (Eds), *Panarchy: Understanding Transformations in Human and Natural Systems*, Island Press, London, pp. 25-62.

Holling, C., Gunderson, L. and Ludwig, D. (2002), "In quest of a theory of adaptive change", in Gunderson, L.H. and Holling, C.S. (Eds), *Panarchy: Understanding Transformations in Human and Natural Systems*, Island Press, London, pp. 3-24.

Hughes, L. and McMichael, T. (2011), *Critical Decade: Climate Change and Health*, Climate Commission Secretariat (Department of Climate Change and Energy Efficiency), Commonwealth of Australia, Canberra.

Hunter New England Health (2007), *Storm Devastation Brings Out the Best in US, Hunter New England Health Matters*, 20th ed., June/July, available at: www.hnehealth.nsw.gov.au/_data/assets/pdf._file/0014/40271/June-July_Special_issue.pdf (accessed 14 April 2015).

Linnenluecke, M. and Griffiths, A. (2010), "Beyond adaptation: resilience for business in light of climate change and weather extremes", *Business & Society*, Vol. 49 No. 3, pp. 477-511.

Loosemore, M. (2000), *Crisis Management in Construction Projects*, Americal Society of Civil Engineers, New York, NY, p. 180.

Loosemore, M., Carthey, J., Chandra, V. and Chand, A.M. (2010), "Risk management of extreme weather events: a case study of Coffs harbour base hospital, Australia", in Egbu, C. (Ed.), *Proceedings 26th Annual ARCOM Conference*, Vol. 2, Association of Researchers in Construction Management, Leeds, pp. 1239-1246.

Loosemore, M., Carthey, J., Chandra, V. and Chand, A.M. (2011), "Climate change risks and opportunities in hospital adaptation", *International Journal of Disaster Resilience in the Built Environment*, Vol. 2 No. 3, pp. 210-221.

Loosemore, M., Chow, V. and Harvison, T. (2013), "Inter-agency governance risk in managing hospital responses to extreme weather events in New South Wales, Australia: a facilities management perspective of shared situational awareness", *Construction Management and Economics*, Vol. 31 No. 10, pp. 1072-1082.

Loosemore, M., Chow, V. and McGeorge, D. (2012), "Modelling the risks of extreme weather events for Australasian hospital infrastructure using rich picture diagrams", *Construction Management and Economics*, Vol. 30 No. 12, pp. 1071-1086.

Loosemore, M., Chow, V. and McGeorge, D. (2014), "Managing the health risks of extreme weather events by managing hospital infrastructure", *Engineering, Construction and Architectural Management*, Vol. 21 No. 1, pp. 4-32.

McGeorge, D., Chow, V.W., Carthey, J. and Loosemore, M. (2011), "Modelling the impact of extreme weather events on healthcare infrastructure using rich picture diagrams", in Egbu, C. and Lou, E.C.W. (Eds), *Proceedings 27th Annual ARCOM Conference*, Association of Researchers in Construction Management, Bristol, pp. 973-981.

Markus, T.A., Whyman, P., Morgan, J., Whitton, D., Maver, T., Canter, D. and Fleming, J. (1972), *Building Performance*, Applied Science Publishers Ltd, London.

Morgan, D.L. (1997), *Focus Groups as Qualitative Research*, 2nd ed., Sage, London.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York, NY.

O'Brien, S. (2009), "Hospitals flooded with emergencies", *Brisbane Times*, Fairfax Digital, 21 May.

O'Rourke, T. (2007), "Critical infrastructure, interdependencies, and resilience", *Bridge-Washingtom National Academy of Engineering*, Vol. 37 No. 1, pp. 22-29.

Office of the Assistant Secretary for preparedness and response (OASPR) (2012), *Healthcare Preparedness Capabilities: National Guide for Healthcare System Preparedness*, US Department of Health and Human Services, Washington, DC.

Powell, R.A. and Single, H.M. (1996), "Focus groups", *International Journal for Quality in Health Care*, Vol. 8 No. 5, pp. 499-504.

Rodriguez, H. and Aguirre, B.E. (2006), "Hurricane Katrina for the healthcare infrastructure: a focus on disaster preparedness, response and resiliency", *Frontier of Health Service Management*, Vol. 23 No. 1, pp. 13-24.

Schulenberg, U. (2009), "Flooding disrupts hospital. The Advocate Gold Coast", *APN News & Media*, 3 April.

Somekh, B. and Lewin, C. (2005), *Research Methods in the Social Sciences*, Sage, New Delhi.

Warren, C.M.J. (2010), "The role of public sector asset managers in responding to climate change: Disaster and business continuity planning", *Property Management*, Vol. 28 No. 4, pp. 245-256.

Young, R.A. and Collin, A. (2004), "Introduction: constructivism and social constructionism in the career field", *Journal of Vocational Behavior*, Vol. 64 No. 3, pp. 373-388.

Zimring, C., Joseph, A., Nocoll, G.L. and Tsepas, S. (2005), "Influences of building design and site design on physical activity: research and intervention opportunities", *American Journal of Preventive Medicine*, Vol. 28 No. 2, pp. 186-193.

Further reading

Chand, A.M. and Loosemore, M. (2013), "Reconceptualising hospital facility resilience to extreme weather events using a panarchy model", in Smith, S.D. and Ahiaga-Dagbui, D.D. (Eds), *Proceedings 29th Annual ARCOM Conference*, Association of Researchers in Construction Management, Reading, MA, pp. 1209-1218.

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