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Living through extreme weather events and natural disasters: How resilient are our high-rise high-density typologies?

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Abstract

The inner city Brisbane suburbs of the West End peninsula are poised for redevelopment. Located within walking distance to CBD workplaces, home to Queensland's highest value cultural precinct, and high quality riverside parklands, there is a once-in-a-lifetime opportunity to redevelop parts of the suburb to create a truly urban neighbourhood. According to a local community association, local residents agree and embrace the concept of high-density living, but are opposed to the high-rise form (12 storeys) advocated by the City's planning authority (BCC, 2011) and would prefer to see medium-rise (5-8 storeys) medium-density built form.

Brisbane experienced a major flood event which inundated the peninsula suburbs of West End in summer January 2011. The vulnerability of taller buildings to the vagaries of climate and more extreme weather events and their reliance on main electricity was exposed when power outages immediately before, during and after the flood disaster seriously limited occupants' access and egress when elevators were disabled. Not all buildings were flooded but dwellings quickly became unliveable due to disabled air-conditioning. Some tall buildings remained uninhabitable for several weeks after the event.

This paper describes an innovative design research method applied to the complex problem of resilient, sustainable neighbourhood form in subtropical cities, in which a thorough comparative analysis of a range of multiple-dwelling types has revealed the impact that government policy regarding design of the physical environment has on a community's resilience.

The outcomes advocate the climate-responsive design's role in averting the rising human capital and financial costs of natural disasters and climate change.

Keywords subtropical climate, multi-storey apartment buildings, resilience, liveability, cross-ventilation

Introduction

In Australian urban centres urban consolidation and compact urban form are viewed as key strategies to manage significant urban population growth and contain urban sprawl sustainably. (Qld Govt, 2009). Multi-residential buildings will play an important role in facilitating the redirection from low-density suburbia to higher urban densities. However, a major flood event in January 2011 has exposed how contemporary building design and construction practices, coupled with regulatory and planning issues, appear to have compromised the resilience and habitability of multi-storey residential buildings.

According to Kenworthy's 84-city study of automobile dependence, urban density and CO₂ emissions have a direct, inverse correlation (Kenworthy, 2003 cited in UN-Habitat, 2008). Compact cities with increased density are associated with lower energy consumption and reduced CO₂ emissions. Historically, Brisbane has had high rates of car-use, but low rates of air-conditioned buildings. Now, rapidly increasing numbers of air-conditioned dwellings are a growing phenomenon due to the combination of affluence, cheap energy and acceptance of poor design. Paradoxically, peak electricity loads are increasing as density increases. This paper will show how this trend is particularly marked in recently-constructed multi-residential buildings. Ironically, South East Queensland's (SEQ) subtropical climate positions the region well to embrace a form of urban settlement that is less dependent on cars and air-conditioning. Brisbane's subtropical climate is warm and humid in summer, with dry cool winters. The city does not experience the extremes of heat and cold endured in other climates, and humidity is alleviated by prevailing breezes. Yet commercial and household air-conditioners are increasingly contributing to urban electricity consumption and residential air-conditioning loads account for a high percentage of the peak electricity load in summer (Engineers Australia, 2010, and

Pricewaterhouse Coopers, 2006) reflecting international trends in both developed and developing countries (UN-Habitat, 2008).

Local communities often view higher-density urban form negatively (Troy, 1996) and media reports regularly link higher densities with a perceived loss of urban character and open space. Articles by Frew *'Battle for beauty in a city going flat out'* (2008) and Fraser and Gaynor *'How population growing pains are about to reach new heights'* (2010) are typical. On the other hand, the West End community is broadly supportive of urban renewal but is not supportive of built form which implies towers taller than eight storeys high (WECA, 2008). In principle, high density buildings and precincts within sub-tropical environments can be designed to more effectively respond to the climate to suit locals' love of outdoor living, and to reduce pressure on energy infrastructure. Yet, the converse seems to apply with much contemporary urban development ignoring or negating the positive effects of the natural climate and forcing residents to rely on air-conditioning for thermal comfort, and leading to public perceptions of low amenity of the buildings themselves and the surrounding neighbourhoods. Policies which promote compactness and densification, if not accompanied with appropriate policies and principles to support good urban design and architectural quality, are likely to further undermine the community's confidence in the liveability and desirability of higher densities in the SEQ region's cities.

The concept of 'liveability' is linked to a range of factors that are affected by planning and urban design such as quality of life, health, sense of safety, access to services, cost of living, comfortable living standards, mobility and transport, air quality and social participation (VCEC, 2008; Howley et al, 2009). Liveability has been broadly described by VCEC (2008) as "the well-being of a community and represents the characteristics that make a place where people want to live now and in the future". This paper sets out to link resilience to liveability, and to examine whether a general reassessment of certain multi-residential housing archetypes is required to inform future urban growth management.

A major flood event in the Brisbane River in January 2011 put resilience of urban places and systems to the test and provided a timely, if unwelcome, opportunity to investigate how high-density residential typologies perform without electricity when power supplies were disconnected to parts of Brisbane for several days in Summer 2011. This research was conducted in the inner urban area of West End (taking in South Brisbane and Highgate Hill) where urban consolidation policies began to be implemented almost a decade ago. Located within walking distance to Brisbane's Central Business District, and home to Queensland's highest value cultural precinct and high quality riverside parklands, West End typifies neighbourhoods undergoing urban renewal of post-industrial sites. According to the West End Community Association, there is "a once-in-a-lifetime opportunity" to redevelop parts of the suburb to create a truly urban neighbourhood (WECA, 2008). The West End peninsula is also the location of several long-established apartment buildings and many newer multi-residential developments representing a variety of typologies. It was one of the Brisbane riverside suburbs that were heavily impacted by the flood.

In this study, though not necessarily regarded as high density in other contexts, high density buildings are identified as 3 - 10 storeys according to Brisbane City Council housing codes (Brisbane City Plan 2000, 2009). In the Queensland context, it is generally accepted by planning authorities that as densities increase, the number of storeys in buildings must also increase. This is true up to a point, but the relationship between density and building height is not directly correlated. Firley and Stahl's (2009) comprehensive comparative typological analysis of a range of urban housing types in various cities around the world show some of the highest densities to be in low-rise cities.

Nevertheless, apartment buildings taller than three storeys were quite rare in Brisbane until the 1980s. Certainly, at the time of the last major flood in the Brisbane River (1974) few tall

residential buildings existed along the inner-urban reaches of the river. Since then, many new towers have been constructed on what is generally considered 'premium' riverside land offering views, open space and breezes. Many more dwellings and residents were affected by flooding in 2011 than in 1974. After the 1974 flood, various flood mitigation measures were put in place in upstream catchments, including a major dam, and new buildings were approved on the basis of habitable areas being above a certain flood datum. Water rose to 500mm above this level in at least two of the buildings examined in this study whose ground floors were at datum. Most new buildings had one or two basement parking levels below the datum.

This research addresses a multitude of serious issues that became apparent throughout and beyond the flooding crisis and associated power outage. In the first instance, these issues arose when authorities were compelled to disconnect power to the area in the face of rising flood. In the longer term, because many of their vital services' electronic controls were located in basements and were damaged by flood water, some apartment buildings did not regain full functionality for months after the event. The salient issues which faced residents of multi-storey apartment buildings as a result of the extraordinary flood event were: basement inundation without water pumps; vertical access and mobility issues without elevators; poor ventilation and air quality issues as apartments became overheated and stifling without air-conditioning; loss of potable water for drinking, bathing and clothes washing without booster pumps; disruptions to communications phone and internet cabling; sanitary issues without flushing toilets; lack of security without electronic locking; and lack of fire safety including failure of fire sprinkler systems and alarms.

One of the main motivations for this research is to explore whether buildings containing multiple dwellings can maintain functionality, or recover quickly, in the event of loss of electrical power as a result of natural disasters or other causes. Understanding the factors that influence residents' perceptions of liveability in high-density locations can assist with the planning, management and design of high-density residential buildings and neighbourhoods to create supportive and sustainable cities. Certain design aspects of multi-storey apartment buildings were identified as likely to affect occupants' activities, use, comfort and well-being. The investigation probed how energy-dependency, access and circulation systems, access to natural ventilation; parking; waste management, and open spaces are interlinked. This paper describes some of the findings of the research which grouped design elements that are regulated by building codes (ABCB, 2011) and some by planning codes.

Research design

The central objective of this research was explore whether contemporary high-density high-rise residential building typologies support their occupants during a crisis – and what lessons can be taken from this to enhance liveability. The research was conducted at the building level, with implications for the neighbourhood context. The question lends itself to a case study approach which is appropriate “when the focus is on a contemporary phenomenon with some real-life context” (Yin, 1994).

In order to uncover multiple factors and explain and describe how these factors overlap to lead to particular outcomes such as the degree of resilience multi-storey apartment buildings offer their occupants, the research combined qualitative methods in four phases commencing with an active appraisal of the area; multi-storey apartment buildings were mapped in both flooded and non-flooded areas using internet-based methods; and categorised according to circulation type and physical form; and finally, a series of semi-structured interviews were conducted with the residents of four case study buildings selected for more in-depth exploration. A range of regulatory issues regarding access and egress, fire safety and planning codes were also reviewed.

Using the websites *Google Earth* and *Nearmap*, multi-storey residential buildings in the defined locality were first identified visually using various search parameters based on building classification (according to the National Construction Code of Australia, ABCB, 2011), building systems, and site topographical location. Buildings selected were limited to those over three storeys in height, and displaying evidence of systems that were considered likely to be electricity-dependent such as elevator shafts, or HVAC plant. Seventeen (17) multi-storey apartment buildings were mapped by this method. Nine (9) of these were inundated by flood or storm-water. Figure 1 shows the geographical spread of cases, including flooded zones. This was not intended to be an exhaustive survey of all existing multi-storey buildings in the area, nor of all the residential buildings that were impacted by the flood, but the data collected is representative of buildings varying in their layouts and circulation types, physical forms, heights, locations and dates of construction, allowing multiple case studies to be compared.

In order to compare the likely impacts of electricity shortage on occupants of different combinations of design parameters, information about the selected buildings was collated in a database. All seventeen buildings were visited, and data regarding physical attributes was recorded using visual survey techniques (digital photography, sketches and notes using a template to ensure consistent fields of data were gathered for each building). Information regarding typical floor plans was retrieved from developers' or real estate agents' websites, and cross-checked with visual analysis. Each case was categorized according to Sherwood's (1978 and 2002) system of typological analysis for circulation type and physical form. Examination of the buildings in this way was important to indicate potential for access to natural light and ventilation. The data is summarised in Table 1.

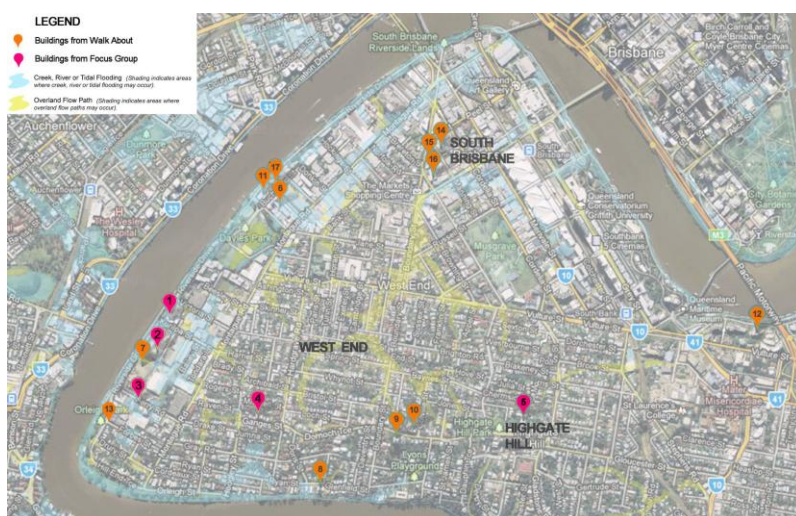


Figure 1 Location of selected Multi-storey Apartment Buildings on the West End Peninsula.
Source: Google Maps and Near Map January 2011

Finally, residents involved in the owners' management committees of several buildings were invited to participate in a series of semi-structured interviews which would provide information on the building users' perspectives from an informed point of view. Residents of Buildings 1, 2, and 3 were contacted through a local community organization. Additional data on Building 4 was gathered by contacting residents directly to obtain information. Respondents were all owner/occupants of dwellings. Six participants, three male, and three female, representing four buildings were interviewed.

Results

In order to gain an understanding of the composition and development over time of the urban fabric of West End, a group of architectural studies graduates conducted an active review of the 'trans-sect' of the West End Peninsula from the City of the Brisbane River to the St Lucia reach, on foot. The group recorded observations photographically and in note form. The 'walkshop'

revealed that development patterns have generally been high density but low-rise. Highly diverse in both form and use, but due to the predominant scale of two-to-three storeys on small lots, buildings were unlikely to be severely disrupted by lengthy power outages. It quickly became apparent that larger scale developments higher than three storeys were more likely to be impacted negatively by loss of power and services. The new larger scale developments on combined or amalgamated sites presented lift cores, transformers on street frontages, and driveways to basement car parks with over-scaled openings to accommodate large waste management vehicles on site. The main observation of the public realm generally was the ubiquitous presence of large mobile waste bins on sidewalks and within property boundaries, with most properties having two 250litre bins for every tenancy.

The data in Table 1 below illustrates the large number of dwellings represented by the multi-storey apartment type of building and reflects economic and regulatory trends in property development in the Brisbane market over recent decades. Only four of the buildings were over eight storeys in height. One of these was completed in 1961, and two were constructed during the 1980s building boom. The model adopted by developers in the first decade of the 21st Century has tended overwhelmingly to be eight storeys or less. Nine of these buildings are located in the low-lying urban renewal area.

Table 1 Summary of Typological Analysis of Multi-Storey Apartment Buildings

Case Study Building	Date	Height above ground (Storeys)	No of dwellings	Circulation type (Sherwood, 1978 and 2002)	Physical form (x =no of blgs) (Sherwood, 1978 and 2002)	Parking (levels)	Flood zone
1	2002	6	54 apartments + 5 townhouses	Gallery access	Courtyard	U/ground (1)	Yes
2	2007	6	76 apartments + 7 townhouses	Double loaded corridor	Slab	U/ground (2)	Yes
3	2009	7	34 apartments	Point access	Tower	U/ground (2)	Yes
4	1970	6	24 apartments	Point access	Tower	At grade (1)	No
5	1960	18+	98 + 49 apartments	Point access + Gallery acc	Tower Slab	Abv/grnd (4) At grade (1)	No No
6	2011	10	84 apartments + 5 townhouses	Gallery access	Slab (2)	U/ground (2)	Yes
7	2011*	8	77 + 91 apartments	Double loaded corridor	Slab (2)	U/ground (2)	Yes
8	1985	7	14 apartments	Point access	Tower	U/ground (1)	Yes
9	1981	13	49 apartments	Point access	Tower	U/ground (2)	No
10	1982	7	45 apartments	Point access	Tower (2)	Abv/grnd (2)	No
11	2009	6	52 apartments	Point access	Tower (2)	U/ground (2)	Yes
12	1987	14	42 apartments	Point access	Slab	U/ground (2)	Yes
13	2011*	8	297 apartments	Double loaded corridor	Slab (3)	U/ground (2)	No
14	2011	7	85 apartments	Point access	Perimeter Block (2)	U/ground	No
15	2007	6	Approx 48 apartments	Point access	Perimeter Block (3)	U/ground	No
16	2005	5	22 apartments	Point access	Perimeter Block	At grade (1) U/ground (1)	No
17	2004	7	65 apartments + 5 townhouses	Double loaded corridor	Slab	U/ground (2)	Yes

*Substantially complete but unoccupied during Jan 2011.

Table 2 describes critical building systems which are dependent on a continuous supply of energy. All the buildings have elevators, with many having two or more. Ducted air-conditioning is present in all the buildings that were constructed since 2002. None of the older buildings have ducted air-conditioning though numerous individual apartments have split-systems installed. Only three buildings do not have centralized fire sprinklers. All but three buildings have electronic building security; most have intercom entry systems. All have pumps for draining sumps or filtering swimming pools. All have electric motors for a variety of purposes. All the buildings in the study shared a temporary (almost week-long) power outage, affecting vertical access and other systems. Residents of buildings which were inundated had power restored to

isolated parts of the buildings as soon as it was safe to do so, but most of the systems considered to essential to living in multi-storey apartments were not returned to service for weeks, and sometimes months.

Table 2 Critical Building Systems

Bldg	Date	Height (Storeys)	Elevators (number)	Air Conditioning	Centralised Fire Sprinklers	Sumps	Electronic Security	Other Electric Motors
1	2002	6	1	Ducted	Y	Y	Y	Y
2	2007	6	2	Ducted	Y	Y	Y	Y
3	2009	7	1	Ducted	Y	Y	Y	Y
4	1970	6	1	N	N	N	N	N
5	1960	18+8	2+0	N	N	N	Y	N
6	2011	10	3	Ducted	Y	Y	Y	Y
7	2011*	8	4	Ducted	Y	Y	Y	Y
8	1985	7	1	N	Y	Y	N	Y
9	1981	13	1	N	Y	Y	Y	Y
10	1982	7	2	N	N	Y	N	Y
11	2009	7	1	Ducted	Y	Y	Y	Y
12	1987	14	2	Ducted	Y	Y	Y	Y
13	2011*	8	3	Ducted	Y	Y	Y	Y
14	2011	7	2	Ducted	Y	Y	Y	Y
15	2007	6	3	Ducted	Y	Y	Y	Y
16	2005	5	1	Ducted	Y	Y	Y	Y
17	2004	7	2	Ducted	Y	Y	Y	Y

*Substantially complete but unoccupied during Jan 2011

The research identified a number of critical systems failures due to power outage which had a significant impact on residents' wellbeing, comfort and safety and shows that the more energy-dependent buildings are, the more vulnerable they are to failure during power outages.

Flooded basements. Flooding of basement levels occurred for two reasons: when inundated by rising flood-water or when stormwater valves failed and basement sump pumps were unavailable because they were reliant on electric motors and had no back-up power when electricity supply was disconnected. Subsequently, basements flooded and services were damaged including pump motors and controls, elevator cars and motor rooms, lighting, communications, mechanical ventilation systems, building security systems, fire safety equipment and alarms. The ramifications were felt by the residents and owners long after the water had subsided, with many systems remaining out of action for weeks and months.

Mobility issues – vertical access. Authorities were compelled to disconnect electricity as the flood crisis approached. When elevators were immobilised, people were obliged to evacuate buildings using emergency exit stairways. In several buildings, the enclosed stairwells normally reserved for fire exits were dark and became congested with people evacuating, as well as people moving large items up into the buildings from lower levels. Interviews revealed that during evacuations some elderly people felt unable to negotiate multiple flights of stairs, or, conscious of impeding the movement of other residents elected not to evacuate at all (bringing other problems as the crisis progressed over a period of days, such as access to fresh food, safe refrigeration and cooking facilities). During power failures, and long periods of inoperative elevators, stairwells and corridors without the benefit of natural light sources were unlit zones and became a source of anxiety within apartment complexes.

Thermal comfort issues – reliance on air-conditioning. Most of the buildings were not designed with functional cross-ventilation for all dwellings; some apartments and shared corridors did not have operable windows and relied solely on air-conditioning for thermal comfort, and ventilation. With power outages, the majority of dwellings in most post-2000 buildings became uncomfortably hot and stifling. Shared corridors and stairwells were similarly affected. Only one recently-constructed building in the study had functional cross-ventilation for all apartments (Building 6), while all apartments in pre-1987 buildings are cross-ventilated. Though they were not reliant on air-conditioning, residents in older buildings temporarily lost the benefit of ceiling

fans during the four-six day power outage. Some apartments in the new buildings are fitted with automated retractable external sun shading systems to west-facing balconies. These devices had no override for manual operation and were rendered useless, further exacerbating poor indoor conditions.

Building Security. Loss of electronic security systems including automatic roller shutters to basement parking garages presented safety and security issues for all case studies, but were more challenging for the most recently constructed buildings which did not have alternative manual systems, and also had keyless locking and multiple ‘access points’ in locations that could not readily be visually surveyed in the months following the disaster.

Traffic problems. Wholesale evacuations of residents with vehicles towing trailers of personal effects created ‘choke points’ in the car parks of some buildings, and on local streets. West End apartment residents without their own car were obliged to rely on relatives or friends for help to evacuate. Local planning policy is actively aiming at reducing car-dependency, providing public transport and limiting parking ratios in new buildings. Interviews revealed that while some residents embrace the opportunity to forego car ownership, other households still have multiple vehicles and as a result, scarce visitor parking and street parking is often occupied by residents’ vehicles. During the flood emergency, streets were congested with vehicles involved in evacuations. In an example of how vulnerable tightly-coupled elements of complex urban systems are to break-down, the public transport network was one of the first city systems to be shut down during the crisis. Electric trains did not run and buses were halted by flooding of the bridge approaches.

Refuse management issues. Various systems for collection and management of waste were also impacted by flood and power outage to various degrees. Floating bins damaged basement walls and equipment, and spilled rubbish added further contamination. Compactors were unserviceable without power and water damage.

All the buildings in the study were affected by mobility issues, particularly without elevators during the temporary power outage. Had the older buildings been located in flood-prone areas, they too may have sustained more long term impacts, however the older buildings were generally more resilient due to the lack of pervasive electronic systems, and in having more readily usable stairways and corridors with access to daylight and air. Regulatory provisions for access and egress and fire safety have not changed dramatically in the past forty years, apart from dimensional changes to better suit access for people with disabilities which was legislated in 2001 (ABCB, 2011). The main difference between the older and newer examples is design for natural ventilation, with all the older layouts allowing functional cross-ventilation.

Discussion

The research has revealed that the majority of the recently-constructed buildings in the study are eight storeys or lower. Multi-storey apartment buildings are the most expensive of all housing types to develop and construct. As building heights and storeys increase, construction ‘type’ also changes according to the National Construction Code of Australia (ABCB, 2011) which sets minimum standards for safe habitation in terms of structure, fire resistance, access and egress, services and equipment, and energy efficiency as well as certain aspects of health and amenity. In order to avoid a range of regulatory requirements which affect capital expenditure (for example, multiple fire stairs with pressurisation; emergency elevator with back-up power; and relief mechanical ventilation to elevator lobbies) many developers elect to develop multi-residential buildings at the height threshold of 25 metres, or about eight habitable floor levels, which do not require these elements. Once buildings are taller than the 25metre height threshold, other considerations which affect developers’ risk profile come into play, and only a few large developers are able to move to a larger scale of development.

The relationship between 'yield', thermal comfort, circulation and community

Planners seek to facilitate long term resilience of communities through policies that support diversity, yet demographic trends indicate that more and more households will comprise two people or less. Speculative development responds with housing 'product' providing dwellings that appeal to a particular cohort's needs and income. For example, single people, students, young professionals, retired couples without children and so on. The smaller apartments and studios that may appeal to small households are inherently shallow in plan with an increased ratio of external wall area-to-internal floor area. Rather than accept the resultant upward effect this has on capital expenditure, many developers seek to maximise profit by maximising the number of dwellings per floor and minimising floor area taken up by non-saleable shared circulation areas. As a result, many high-density building designs employ the 'double-loaded' interior corridor to access numerous dwellings by the one shared corridor, within fire regulations. However, this strategy usually results in a lack of natural light and ventilation for such corridors, stairways and lobbies. In the Australian context, the resulting energy costs of providing artificial light and air-conditioning to these spaces, often continuously, are not borne by the developer but directly by the body corporate of owners who in turn pass them on to their tenants. Individual dwellings are similarly constrained in terms of access to cross-ventilation and daylight to internalized rooms. Acceptance of the 'double-loaded' interior corridor means that Australian multi-storey housing types are becoming increasingly reliant on active systems for heating, cooling and mechanical ventilation.

Despite changing attitudes toward thermal comfort in affluent societies, (Brager and de Dear 2003) recent research funded by the Australian Research Council into the impacts of higher-density living in subtropical city, found that apartment residents in Brisbane's inner urban locations associate lack of cross-ventilation with an undesirable reliance on air-conditioning, and 83% of survey respondents expressed a preference for natural air flow over air-conditioning (Buys et al, 2008).

Horizontal and vertical circulation systems are powerful drivers of the success or otherwise of both the environmental and social performance of multi-residential habitats. Access and circulation 'pathways' can either block or generate access to light and air, and promote or inhibit a sense of community. Bay (2011) has researched relative levels of frequency of occurrences of social activities that contribute to a sense of community and quality of life in apartment buildings in Singapore and found a strong correlation between both of these factors - corridor configurations which gave residents access to both outdoor climatic comfort and opportunities for social interaction, were most successful in community-building. However, clear demarcation of what is public and what is private space is important (Buys, et al, 2009) in order to avoid the unpleasant situation of people constantly walking past dwellings and looking in whether they mean to or not.

In contemporary developed economies like USA and Australia, stairways are no longer seen as a relevant means of moving through a residential building. As buildings become taller, the 'elimination of everything that goes beyond the purely physical overcoming of a difference in height' leads to impoverishment of shared circulation spaces (Ebner et al, 2010). Though vital as emergency means of escape, stairways are relegated to a secondary role that demands no care in presentation – unpainted concrete walls and stair treads, and vandal-proof fluorescent lighting are *de rigeur*. In the western tradition at least, these spaces are not designed for lingering and are not intended as places to meet others. The opposite trend is now occurring in office buildings where several floors or workplaces are connected by high quality open stairways to encourage communication and movement between floors. Enclosed corridors and stairways in multi-residential buildings represents an uncreative response to regulatory issues and an unwillingness to invest in design effort or non-standardised designs that are not 'deemed to comply' outcomes and which require a slightly higher degree of liaison and collaboration with regulatory bodies to achieve.

The way in which residents are linked to the neighbourhood via transition zones between public space and private realms is also important. Residents of multi-storey towers typically enter the building by a single point (often from a basement car-park) and little pedestrian activity is generated on the adjacent street. In comparison, observations of street-facing dwelling types in Vancouver's new high-density neighbourhoods by Macdonald (2005) suggest that high-density dwellings with entries directly from the street contribute visual interest, activity and social interaction to neighbourhood character, as suggested by urban design theorists, Jacobs (1961) and Gehl (1987).

People generally want buildings that work well for them, and to feel that they have choice in the control of their comfort needs, from noise to air movement (Buys et al, 2009). A building's design, and efficiency of its operation are also influential in the harmonious life of a building's community. Leaman and Bordass (1999) describe chronic performance failures of modern buildings, citing defects ranging from waste caused by energy inefficiency to unwanted noise and irredeemable vandalism – often the result of mismatch between design and the expectations of occupants. Various researchers emphasise the importance of understanding user needs and preferences and the relationship between people and their housing environments (Rapoport, 1969, Cooper-Marcus and Sarkissian, 1986, Buys et al 2009). The results of the study described by this paper revealed a complex set of influences on the resiliency and liveability of multi-storey apartment buildings, from interpretation of building codes to various stakeholders' expectations of project success. The findings indicate an insufficient awareness of these connections between key areas of planning, design, procurement and user expectations, and a lack of accountability between stakeholders involved in a multi-storey residential project. Urban consolidation policies in Brisbane have coincided with an increasing reliance on air-conditioning rather than natural ventilation for dwellings and shared spaces in multi-storey apartment buildings. Over the coming decade, perceptions of design quality are likely to derive more and more from responses to rising costs of water and power, and to the predicted effects of climate change including the incidence of more frequent extreme weather events and the need to reduce occupants' vulnerability to hazard or risk.

Conclusion

Using a qualitative approach in several phases, data was collected on a number of multi-storey apartment buildings in the West End Peninsula in Brisbane, Australia. This research points to how people's experience of a recent flood disaster was dramatically influenced by the type of building they inhabited. The research highlighted how mainstream urban development, and conventional design and construction practices compromised the performance and habitability of certain types of buildings before, during and after the recent flood disaster in the urban areas of Queensland. For instance, reliance on mains power dramatically influenced the impacts experienced by the occupants of multi-storey residential buildings, whether or not they were actually inundated by floodwater, seriously limiting access and egress, and affecting thermal comfort due to the design's reliance on air-conditioning rather than natural ventilation.

Resilience was low in energy-dependent buildings and 'liveability' was unsupported during the crisis and beyond. Further research is needed to explain whether code-compliant designs compromise performance and if so, what needs and expectations of occupants are not being supported by current building codes, and planning schemes. A comprehensive understanding of complex factors is needed for the application of context-driven, resident-centred planning and design principles including a flexible approach to shaping design solutions.

Though the focus of this research has been on the architecture of buildings rather than on planning *per se*, the results demonstrate how policies aimed at achieving compact urban development can result in patterns of development or individual building outcomes not necessarily anticipated by local government whose stated long term aim is to produce high-density urban form that is environmentally, economically and socially sustainable. The

implications of this research for subtropical cities is to advocate the value of climate-responsive design for achieving sustainable outcomes that are adaptable to climate change, and particularly design's role in averting the rising human and financial costs of natural disasters.

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