

FLEXIBLE AND ADAPTABLE HOSPITALS – AUSTRALIAN CASE STUDIES

J. Carthey¹ and V. Chow²

ABSTRACT

In 2009, a literature review uncovered different international approaches to achieving flexible and adaptable health facilities and concluded by recommending further research focussing on Australian hospitals to identify key site issues, design features, and major upgrades that have influenced longer term responses to changing modes of service delivery and other demands in local settings. Responding to these recommendations, this second stage research was conducted by reviewing further relevant literature and project documentation for five case studies, visiting and documenting key adaptability features of each case study facility and consulting with health facility personnel where available. Findings include that longer-term flexibility is assisted by: generous site area, lower rise hospital buildings along a horizontal circulation spine ('hospital street'), surplus building services capacity facilitating easy expansion/alteration, and a consistent workable planning grid supporting a range of standardised room sizes. Future investigation should consider the impact of high land values on site utilisation especially in terms of future proofing multi-storey buildings, and how to assist health clients decide when 'enough' flexibility has been provided.

KEYWORDS

adaptability, case study, flexibility, healthcare facilities, hospitals

BACKGROUND

In 2009 a first stage research study was completed for Health Infrastructure NSW that commenced with a literature review looking at how cost-effective flexible and adaptable health facilities could be achieved with an effective life of 50 years or more. A desktop examination of 19 international case study hospitals followed; chosen from the literature review results because each demonstrated one or more definable approaches to future proofing and analysis was possible due to the availability of information. The study concluded that definitions of flexibility and adaptability were inconsistent, recommended standardization of these and concluded that flexibility should be considered as a system applicable at many levels of project design and implementation rather than as a standalone concept or 'motherhood statement'. It also concluded that strategic, managerial, operational and other policy issues impact on flexible performance at least as much as the original design, and need to be considered in terms

¹ Faculty of the Built Environment, The University of NSW, Sydney, Australia, email: j.carthey@unsw.edu.au

² Faculty of the Built Environment, The University of NSW, Sydney, Australia, v.chow@unsw.edu.au

of their positive or negative influence on the desired project outcomes and addressed accordingly.

The first study concluded with the recommendation that a selection of Australian case studies should be investigated in more depth in order to test the extent to which flexibility and adaptability have been successfully applied in the local (NSW) context. It was also anticipated that more detailed findings could be further extrapolated as design principles for use on future projects. This research responds to these recommendations by concentrating on a set of NSW-based case studies that include Westmead, Blacktown, Mt Druitt, Prince of Wales and Royal North Shore Hospitals and examines these in terms of the assessment parameters developed in the first study.

INTRODUCTION

The reasons for flexible and adaptable healthcare facilities were considered in stage one of this research and so have not been repeated here (J. Carthey, Chow, Jung, & Mills, 2009a, 2009b, 2010). In particular, the first study noted that definitions of designing for ‘flexibility’ and ‘adaptability’ are rarely consistent between projects and in agreement with de Neufville, Lee and Scholtes (2008), adopted as a definition: ‘the provision of options for the future use of healthcare buildings, without the obligation to necessarily exercise those options’ (J. Carthey, Chow, Jung, et al., 2010, p. 105). Further, the nature of these options means that their outcomes and effectiveness can rarely be tested or evaluated until some years after project commissioning and as a result, such evaluations rarely occur. To counter this, a matrix of terms and associated concepts was proposed as shown in Table 1 below to enable a more robust discussion and assessment of flexible and adaptable design. The matrix includes both planning scale (short/long term and micro/macro design phases) and planning strategies in terms of managerial, functional or building system requirements.

As the research client is a major Australian State health system (NSW) examples of approaches adopted by other publicly funded health systems were also sought and analysed in the preliminary phases of the research. For example, illustrating many of the points made in the first research study and indeed the definitions and concepts illustrated in Table 1, the US Veterans Affairs Hospital System (VAHBS) developed by a large government agency addresses the longer term issue of providing flexible and adaptable hospitals to resist obsolescence and issues of declining performance over their life cycles. The VAHBS was first developed in 1972 (the ‘Redbook’ Research Report), revised in 1977, applied to major new or replacement hospitals completed between 1977 and 1995, then reviewed in 2005/6 as the Department undertook advance planning for its first new major hospital projects since the mid-1990s (Department of Veterans Affairs, 2006; Dept of Veterans Affairs, 1972). An extensive series of reports and design guidelines continues this work, including the 2006 report that claims in its Foreword that ‘[i]t has been the VA’s experience that VAHBS projects have not cost more than traditional construction bidding, and have cost less on a life cycle basis’ (Department of Veterans Affairs, 2006, pp. 1-1). The VA approach to healthcare facility design can be characterized as ‘systems integration’ defined in this instance as ‘[t]he combination of a groups of relatively independent parts into a coordinated whole to improve performance through controlled interaction...’ (pp. 1-8). Key features of the

system include ‘modular design with integrated service zones for permanent and adaptable buildings subsystems’ (pp. 2-1), both of which are illustrated in the case studies examined in this research.

Table 1. Definitions of Flexibility and Associated Concepts

Focus	Managerial considerations	Functional requirement	Building system
Micro	<u>Operational</u> Easy to reconfigure, low impact on time and cost (e.g. furniture and interior spaces)	<u>Adaptability</u> Ability to adapt existing space to operational changes e.g. workplace practices	<u>Tertiary</u> 5-10 years lifespan, no structural implications e.g. furniture
	<u>Tactical</u> Involves commitment of capital expenditure; changes not easy to undo (e.g. design of operating theatres, provision of interstitial floors)	<u>Convertibility</u> Ability to convert rooms to different functions	<u>Secondary</u> 15-50 years lifespan, e.g. walls and ceilings, building services capacity
Macro	<u>Strategic</u> Substantial increase in the lifetime of the infrastructure (e.g. long term expansion plans, future conversion to other functions)	<u>Expandability</u> Ability to expand (or contract) the building envelope and increase/decrease capacity for specific hospital functions	<u>Primary</u> 50-100 years lifespan, e.g. building shell
Source	(de Neufville, et al., 2008)	(Pati, Harvey, & Cason, 2008)	(Kendall, 2005)

Further driving the need to extend the lives of healthcare facilities, it was also recognized that the movement towards sustainable healthcare development calls for reductions in embedded energy and greenhouse gas emissions, and the leveraging of these in the reuse of existing buildings. This is another major factor driving the need to design healthcare facilities for flexibility and adaptability in order to ensure a longer life rather than more frequent demolition and rebuilding as presently occurs. In terms of sustainable use of energy Sunand Prasad notes that ‘[w]e badly need accurate metrics that factor in embodied as well as operational carbon to help decide between replacement and renewal’. His point is that older buildings often perform poorly in terms of current energy performance requirements but improving zoning and controls can help; he continues by proposing that ‘[s]tripping down a building to its frame is perhaps the most dramatic level of intervention but still recovers 50% of its embodied energy, and in its rebuilding it can deliver equivalent performance to new construction’ (Prasad, 2011, p. 9). Also in this vein are remarks made by Phil Nedin (2011) of Arup in terms of calls to consider whole life rather than first costs. He further challenges the industry to think about how the healthcare buildings designed today could also be used in 20 years despite changes in models of care, reductions in bed numbers, changes in technologies and other dynamic factors.

The case studies that comprise this research represent examples of many of the techniques expounded in the VAHBS model, and in many instances have also performed well in ways that Nedin suggests are essential, in particular accommodating changing health service needs over time. Each has been analysed in terms of the matrix in Table 1 **Table** with a view to describing some effective approaches to future proofing Australian healthcare buildings which can be extrapolated to the health systems in most

developed countries. The case studies were chosen because they were included as part of the conclusions of the stage one research which suggested comparing them with the mostly international examples considered in that stage of the research. Each is a large urban hospital constructed up to 35 years ago that has undergone at least one major refurbishment or upgrade since first opening. The Royal North Shore Hospital (RNSH) 'brown building' was subsequently added to the study due to the coincidence of its opening in 1977 within one year of Westmead Hospital in 1978. Westmead will very likely continue to operate for another 25-30 years whereas the 'brown building' will shortly be demolished as part of a major Public Private Partnership (PPP) project on the RNSH site due for completion by 2014.

METHODOLOGY

The hypotheses tested by the research were extrapolated from the first stage research, and as developed with the research partners, are summarised below:

1. Planning healthcare facilities (including site master planning) for change (flexibility and adaptability) will encourage and better support future developments (new and refurbished) that will accommodate both foreseen and unforeseen emerging service delivery needs and other functions over time.
2. If healthcare facilities are not planned to change and adapt they will become obsolescent (or dysfunctional) more quickly than those that are planned for flexibility and adaptability.
3. The strategies adopted for healthcare facility flexibility and adaptability as shown in Table 1 will be tested and validated by this research as inclusive and accurate.

For each case study facility, a literature search was conducted which included sourcing documents from design and other consultants known to have been involved with either the original hospital development or with major upgrade projects over its life. In addition, where possible, site facility managers were interviewed informally or consulted using email or telephone, followed up by site visits to each of the facilities. Due to political sensitivities surrounding the current redevelopment project for the site, the RNSH 'brown building' was not visited and reviewed only as a desktop exercise. Project personnel or facility management were also not available at the Prince of Wales Hospital. For these two case studies, literature from the search plus website information were analysed and then compared to the other three case studies of Westmead, Blacktown and Mt Druitt Hospitals.

A timeline for the development of each hospital was prepared from the available information with major upgrades noted. Finally, the development of each hospital was reviewed in terms of its manifestation of longer flexibility and adaptability according to the definitions of the stage one study.

The data for each hospital were collated and organised using an analytical framework that included determination of the principle characteristics of the site such as overall master planning, the built form of the hospital (tower, hospital 'street', site coverage)

and where articulated from project documentation or other sources, strategies incorporated for anticipated future growth or change. Major upgrades (renovations, additions, alterations) were identified and compared in terms of reasons for these and the strategies subsequently adopted with those anticipated at the time of opening of the major hospital buildings. Conclusions were drawn and a report written for the research client - Health Infrastructure NSW- which included recommendations for future proofing NSW healthcare facilities and for future research (J. Carthey, Chow, & Wong, 2010).

RESULTS

WESTMEAD HOSPITAL

Westmead Hospital was the first major project developed following publication in 1974 of the Sax Report: 'A Report on Hospitals in Australia' (Australia Hospitals & Health Services Commission & Sax, 1974) which was seminal in recommending a new philosophy for Australian healthcare delivery including benchmarks for needs assessment and sizing of hospitals. Westmead opened in 1978 with approximately 1000 beds which by 2011, due to changes in the delivery of care, had been reduced by about 200 beds rather than expanding as first anticipated. It was designed by the English architects Llewellyn-Davies Weekes in collaboration with Australian partners, Forrestier-Walker and Borr, and the NSW Government Architect. Drawing from UK hospital planning models such as the Best Buy and Harness systems, Westmead was designed using a strategy of 'indeterminacy' so that it could change in unpredictable ways to cope with different care practices and future advances in technology (Nield, 2008). Because it was expected to be completed in only four years (1974-78) Westmead was built using fast track construction and is one of the earliest examples of this form of contract in Australia. This affected the sequence of construction and various decisions regarding detailing of the facades and floor slabs. The hospital was designed to be modular and building services were zoned to enable easy upgrade or alteration in the future. In the mid 1990s the Royal Alexandra Hospital for Children was relocated to the site from Camperdown to become the 350-bed Children's Hospital at Westmead, and like Westmead Hospital this was also designed to be readily changed and expanded (Constructional Review, 1992). In addition to many smaller developments, in 2008 a major development on the site implemented components of the Western Integrated Network (WIN) Strategy for the Western Sydney Area Health Service. This redeveloped several departments including intensive care units, allied health areas, women's health and newborn care, cancer treatment services and the renal unit. Extensive upgrades of the hospital's engineering plant and services were also undertaken (Leighton Holdings, 2010b).

According to Lawrence Nield the design of Westmead Hospital was 'radical for its time' demonstrating relatively revolutionary planning strategies that included the organization of individual hospital units and the need to anticipate and plan for future growth and change (Nield, 2008, pp. 225-226). Six-storey inpatient buildings and three-storey service blocks were arranged around major movement routes or 'streets' designed with the capability to be extended in response to future growth and change. Almost every main block was designed with a free end to enable future extension or alteration

without incurring excessive capital cost or disruptions to hospital functioning. This centralised plan form with a potentially linear pattern of growth allowed the more determinate elements of the hospital to be located centrally along the spine to form a core set of departments and functions. Less determinate elements were then attached to this core and spread outwards along the secondary circulation routes to ensure that they could be expanded independently in terms of the strategy described above. It was anticipated that new elements could be added to the complex along the spine or core to meet future needs (Architecture Australia 1977). Other features included strict zoning of functions and services at strategic and tactical levels with planning based on a 7.2m grid north to south and multiples of this from east to west (Burgmann, 1982). Structure, services and finishes were zoned to minimize clashes, non-load bearing partitions were used so that design and construction could proceed independently of final room layouts and floor screeds were used throughout all major blocks which enabled the resolution of final bathroom layouts to be deferred until late in the project. In terms of building services, a system was devised comprising standard floor penetrations and double columns to accommodate services thus enabling future alterations to these without disrupting operation of the building.

In 2004-2008 the major works undertaken for the WIN strategy included construction of a building (Block E) across the north-eastern end of the current Westmead hospital buildings across the ends of blocks D and C. Refurbishment and additions to existing building blocks in that vicinity were also made including to the University Clinics building at the end of the Diagnostic and Treatment Block. This development effectively closed off the hospital street or core circulation spine, thus preventing any future expansion of the hospital in that direction. Given the reduction in bed numbers since completion of the original hospital and likely continuation of that trend into the future, the expansion of wards (related to increased inpatient bed numbers) seems to no longer be a priority for the Health Service. Alternative reasons for expansion, for example the need for new services such as rehabilitation or increased diagnostic and treatment capacity, appear to have driven this particular project.

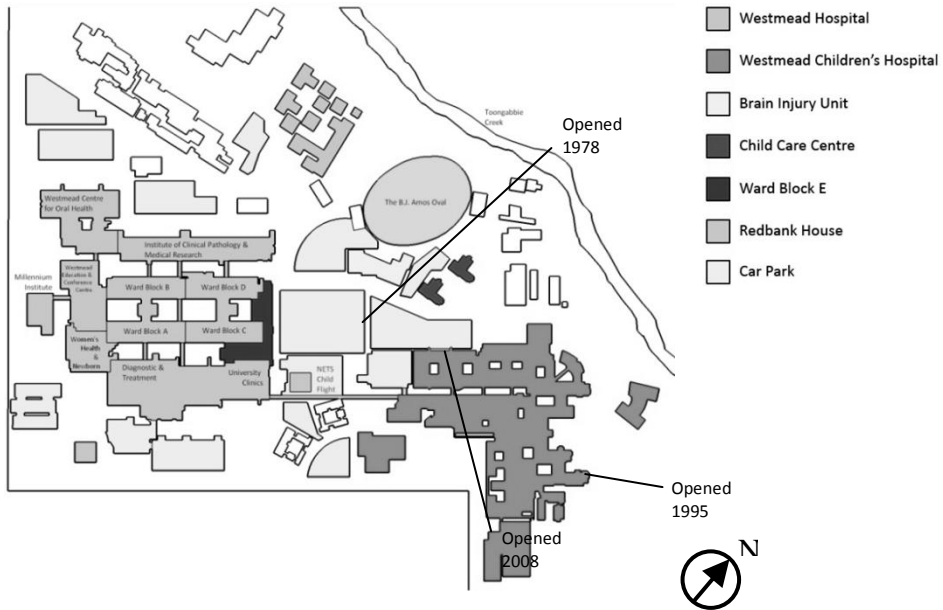


Fig. 1. Westmead Hospital Campus

The Children’s Hospital at Westmead was also built around a naturally lit double height internal street. This complex has four levels and is constructed of reinforced concrete with 7.2m x 7.2m column grid with flat slab floors and dropped panels (Constructional Review, 1992). Infill and cladding materials include rendered blockwork and powder-coated metal. Areas requiring heavy servicing are provided with a full height undercroft allowing for easy replacement and upgrading of mechanical and electrical systems (Wislocki, 1996, p. 64). The future of the Westmead site includes options for expansion/ replacement/ decanting/ demolition of the hospital plus zones for other uses such as a biomedical hub precinct. At the present time, the Millenium Institute on the site is being upgraded and expanded along with other smaller scale refurbishment works in various parts of the facility. See Figure 1 above.

BLACKTOWN HOSPITAL

First opened in 1965 Blacktown Hospital has expanded from an original 160 beds to about 365 beds in 1987. In the 1990s the hospital underwent a major redevelopment that was finally commissioned in 2000 (NSW Health, 2010). The planning phase for another major redevelopment is currently underway that will respond to the health service needs and planning principles outlined in the Concept Master Plan Report for the site prepared in 2007 (R. Carthey, Ryan, Cameron, & Driscoll, 2007). Over the years several buildings have been added to the site; however the largest change was the construction of the new main hospital building that opened in 2000. According to Lawrence Nield, the main public hospital building is now a ‘linked pavilions form’ that is often used for smaller country hospitals and for upgrades of suburban hospitals. The site topography determined the location of the main entry at level three with visitor access to the fourth level inpatient facilities by stairs. The building sections are long, narrow and broken up

by courtyards which express the circulation patterns and act as a way finding device. The general inpatient units are laid out in a double-loaded single corridor form (rooms to both sides of the corridor) with the units laid end to end (Nield, 2008, pp. 231-232). The location of the main hospital buildings on Blacktown Road offers good access from the main road and leaves most of the remaining site available for future development.

The redevelopment was planned to be flexible, adaptable and expandable with features that included the use of non-structural walls, weight bearing slabs, and easy access to hydraulics and electrical/mechanical services to enable straightforward reconfiguration, extension or upgrade in the future (Project Planning Team - Blacktown/Mt Druitt Hospitals Redevelopment, 1996a, 1996b). The 2007 masterplan report included concept plans for a future redevelopment scheme that demonstrated that the building envelope could be extended quite easily through the addition of simple extensions to each end of the hospital and in adjacent locations either side of the main east-west axis. This would provide up to 20,000m² of additional floor area to meet the defined service needs.

Although Blacktown and Mt Druitt Hospitals effectively function as one hospital, and are within 10 minutes' drive of each other, their campuses are distinct and each has its particular focus. For example, the Blacktown campus provides high level inpatient and outpatient services and has the capacity to manage complex patients who require specialist acute care. Mt Druitt provides services to its local community and surrounding region in a complementary manner and these include 24-hour emergency care, cardiology including outpatient cardiac rehabilitation, consultation liaison psychiatry services, a comprehensive paediatric service, aged care rehabilitation, outpatient pulmonary rehabilitation, palliative care and planned surgery including orthopaedics with an Area-wide role in provision of major joint replacement surgery (Health Services Development Unit, 2010).

MT DRUITT HOSPITAL

Mt Druitt Hospital opened in 1983 with 200 beds and although various refurbishments, additions and alterations have occurred the main fabric of the building has not been extensively changed. Various additional buildings have been added to the site either located in close proximity to the main circulation spine or more remotely on the site. See Figure 2 below.

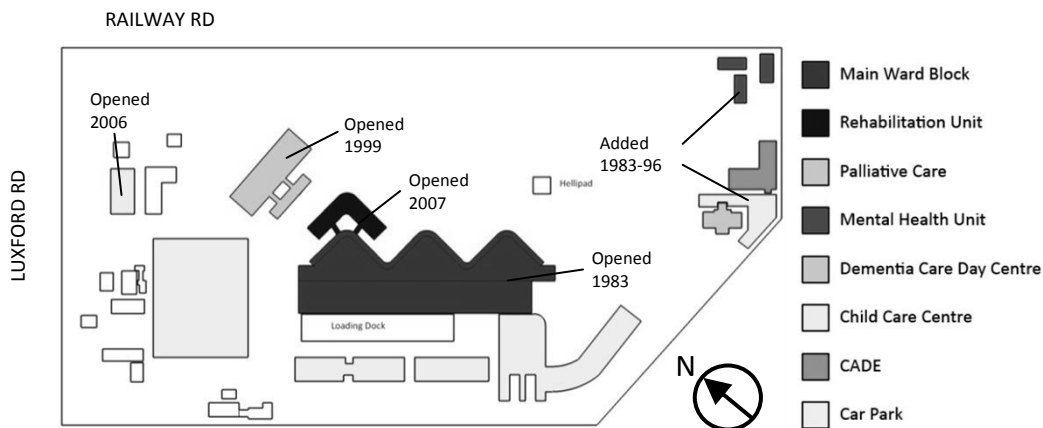


Fig. 2. Mt Druiitt Hospital Site

According to Lawrence Nield (2008), architect for the hospital, Mt Druiitt Hospital was planned using a computer program called TOPAZ – Technique of Placing Activities in Zones, developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), to maximize efficient layout and location of the hospital departments. Studies of internal traffic in similar hospitals informed the arrangement of spaces, and in this case determined the two-storey layout that relies on a hospital street for major circulation that also becomes an organizing principle for future growth and change. The hospital street and the plant rooms act as a spine for the development that was ‘simple to construct, easy to expand or change internally, and had a minimum of external wall area’. Airconditioning and air handling and distribution are placed on a special floor above the upper level, allowing adjustment and maintenance to be carried out without intrusion into clinical areas (Builder NSW, 1984; Nield, 2008). Nield classifies the hospital as an ‘unbundled’ typology in that its form was determined by site and care delivery model.

Triangular shaped nursing units (inpatient wards) are placed on one side of the street on both levels. The triangular wards were designed to ensure that patients were undisturbed by passing traffic, had good outlooks to pleasant views and their environment was tranquil. At the same time they could still be easily observed, and could also readily see the nursing staff to ensure that they felt secure and cared for at all times. Paediatric wards are placed at ground level and have access to a courtyard play area. They were designed with ‘care-by-parents’ units so that parents could be closely involved with the care of their children. On the other side are located clinical and non-clinical units with treatment and diagnostic services and an entry on the upper floor, and kitchen, dining, pathology, plant and maintenance services on the lower floor. Car parking is also located on this side of the street so that patients would not have to look out at masses of parked cars. Instead they have a view across the surrounding landscape that links to the Mount Druiitt Town Centre (Nield 2008).

The hospital street is a way finding device and visitors can walk along it to the appropriate ward, using the stairs to access lower levels for example to access the children’s ward. The stairs were designed to be open and inviting to assist in convincing

visitors to use them and not the lifts. The hospital was intended to be easy to operate and administer with good connections between wards and service functions such as the kitchen for delivery of food to wards, dining rooms, etc. According to Builder NSW (1984) significant passive and active energy conservation measures were included in the building. Future expansion can be dealt with by extension of the hospital street at either end while modification of clinical and support facilities can be achieved by extension to the south (Heath, 1984). At present, the Mt Druitt camps focuses on planned surgery, sub-acute rehabilitation and palliative care services and it is likely that future expansion will increase capacity in these areas and also in emergency, mental health, oral health and outpatient clinics for children and adults.

PRINCE OF WALES HOSPITAL (POWH)

The POWH site has been used for healthcare and related purposes since 1858. Initially used as an asylum for destitute children, it first became a hospital during the First World War and has subsequently been through several incarnations as a repatriation hospital and teaching hospital. From the mid 1990s onwards, a major redevelopment on the site added the Royal Hospital for Women (relocated from Paddington), a new acute care services building including 19 operation theatres, three-level private hospital, research facilities, mental health, an upgraded children's hospital and various other services and facilities.

The site is very heavily utilized and accommodates three heritage buildings that cannot be demolished. Land values are high and the site has been built up to leverage this value with several multi-storey buildings that are deep-planned, reliant on airconditioning and artificial lighting. A recent local council precinct study anticipates future expansion of the campus into surrounding areas in the future that would require possible land rezoning, plus reorganization of site entry points and connections to the local community (Randwick City Council, 2010).

ROYAL NORTH SHORE HOSPITAL (RNSH) 'BROWN BUILDING'

The RNSH 'brown building' which opened in March 1977 was included in this study as a comparator to Westmead Hospital which opened in late 1978. The RNSH building known as the 'Main Block' will shortly be replaced by a new PPP hospital due to open in 2014 (Leighton Holdings, 2010a). It was constructed with the capacity to hold 650 beds over seven levels (6-12) above a six-level diagnostic and administrative podium below. On top of the ward levels are two floors of plant forming levels 13 and 14. The tower is 'H'-shaped with the ward areas occupying the 'limbs' of the 'H' with administrative areas, the transport core and service areas in the centre of each floor. Each 25-bed ward was designed on the 'racetrack' principle with a double corridor with patient rooms on the outside walls and staff working areas in the middle. Although the design was standardized to enable future flexibility, each ward is allocated to a single specialty although some specialties use more than one ward. Special needs have been accommodated through the use of local modifications such as radiation shielding or by the use of mobile equipment.

The difficulties in modifying this building to support new models of care have clearly been a factor in the decision to demolish it subsequent to construction of the new hospital. Modifying it while parts of it remain operational on a functioning hospital campus would be especially difficult given limited access and the need to contain dust, noise and rubbish without disturbing or endangering patients and staff working in the hospital.

DISCUSSION

FEATURES THAT ASSIST WITH LONGER TERM FLEXIBILITY AND ADAPTABILITY

Each case study was assessed in accordance with the principles of the stage one study matrix (see Table 1). The planning strategies adopted were mostly focused on enabling long term changes to the building envelope (mostly extension or expansion) to accommodate new healthcare services or alternatively changes of use that required internal remodelling - rather than simply using spaces unmodified for these new purposes. One of the limitations of this research was that largely due to time constraints, it did not examine in detail the use of this last strategy on the projects and as described in the top row of Table 1. Although this approach was validated anecdotally by several of the facilities it should be examined in further depth in future research to understand exactly what features supported it (e.g. room size, shape, etc) or alternatively, worked against it.

Features that do appear to have assisted the case study buildings to change and adapt were identified from the project data and are noted below. Clearly, these were considered desirable because they supported expansion and alteration of the facilities rather than constraining or preventing it.

1. A large site with appropriate healthcare-related zoning (evidence derived from Westmead, Blacktown and Mount Druitt). Maintaining sufficient site area for future expansion or even replacement of some or all of the existing hospital while the existing facility continues to operate is a useful metric for determining appropriate site area. It could also guide master planning approaches to the hospital campus e.g. the 'empty chair' or 'four quadrant' approach demonstrated by the Martini Hospital at Groningen (J. Carthey, et al., 2009b, p. 22).
2. Design around a hospital 'street' or spine with three to six-storey buildings along it. This allows expansion at either end or to various units along the spine - outward or upward (evidence derived from Westmead, Blacktown and Mount Druitt). This strategy also facilitates the refurbishment or upgrade of various parts of the hospital without negatively impacting on the remaining parts in terms of noise or other disruptions.
3. Capacity to upgrade building services on a zone by zone basis (evidence derived from Westmead, Blacktown). A service tunnel can also assist with this as can the double column building services arrangement used at Westmead.
4. Use of a modular grid that supports a range of functions e.g. the 7.2m x 7.2m grid used at Westmead has proved beneficial in reconfiguration of spaces for other purposes. This is also supported by Diamond (2006) in his report for the NHS, and more recently in the latest version of the UK Health Building Notes which proposes a small range of room sizes (12, 16 and 32m²) that fit with standard planning grids

for clinical and clinical support functions (Department of Health Gateway Reviews Estates & Facilities Division, 2010).

ISSUES FOR FURTHER INVESTIGATION

The following issues may be worthy of further investigation and discussion with reference to these and other case studies:

1. At Westmead the strategic provision of courtyards formed a redundancy strategy that later offered the opportunity to turn these courtyards into utility and clinical spaces at a later date. This results in a lesser amount of outdoor space (and possibly reduces the entry of natural light) for the hospital. Does this have a detrimental effect on patients, staff and the quality of the environment?
2. Westmead, Blacktown and Mount Druitt were all built on large, outer urban 'brownfields' or 'greenfields' sites whereas POWH and RNSH are both built on inner urban high land level sites. This has an impact on land values and the need to use the site much more efficiently to leverage that value. The downside is that on the POWH and RNSH it would be much more difficult to justify holding on to vacant land for future expansion than it is for the hospital sites located further west in Sydney where land is less expensive. The other question becomes 'how much land is enough to ensure flexibility over time?'
3. Further investigation of modular grid sizes could prove useful in planning future adaptive strategies. A comparison between Westmead, Blacktown and Mount Druitt suggests that the irregular design of Mt Druitt may have limited its potential to flex over time.
4. Although the findings of this study have shown that the types of flexibility measures that appear to be most useful largely conform to the literature search from stage 1, review of further detail regarding the changes accommodated at Westmead and Blacktown may highlight further questions. For example - how much can a facility designed for one clinical function change to accommodate other functions? The functions accommodated in areas that have undergone alteration need to be compatible with the original function - in terms of spatial requirements, building services and access arrangements. In particular, 'hot floor' operating and similar functional spaces seem to be the most resistant or difficult to change without a major building project. Perhaps because of this most of the changes seen are in secondary clinical spaces e.g. outpatients, clinics, inpatient units, etc. For this reason grouping similar functions together as suggested by BJORBERG and VERWEIJ (2009) and accepting a change or downgrading of function over time could be considered a useful strategy.
5. Maintaining service delivery during a renovation or upgrade is often very important or even essential. There seem to be a number of ways to achieve this, including the provision of interstitial spaces or service tunnels as examples of planning options. In terms of master planning the hospital, long, low, stretched out planning around hospital streets as occurred at Westmead, Blacktown and Mount Druitt all seem to better support service delivery during an upgrade or to minimise the impact of construction on an operating hospital. Podium and tower block approaches (RNSH and possibly POWH) appear to make this more difficult due to disruption from noise, dust, etc.

CONCLUSIONS

The research results largely support the hypotheses tested in that those facilities with actively articulated and designed-in flexibility and adaptability strategies have better supported upgrades and developments over time without requiring extensive demolition and re-building of key hospital buildings. However, although the strategies outlined in Table 1 are largely confirmed by this research they are not yet claimed to be fully definitive or inclusive, especially given the lack of testing of the short term ('no modification') strategies on any of the project due to time and data constraints. Similarly, although not often specifically mentioned as a tactic for encouraging healthcare facility flexibility and adaptability in Table 1, appropriate and sensitive site master planning appears to be a precursor for encouraging and supporting many of the initiatives undertaken, in particular at Westmead, Blacktown and Mt Druitt Hospitals, and inappropriately done, may constrain the effective life of other inner urban hospitals. As a result, future revisions to Table 1 will incorporate site master planning as another primary strategy for ensuring longer life for the building shell and the future expandability of a hospital.

Thus, the extent to which features that promote flexibility and adaptability can be implemented on health projects is not yet fully defined and is the subject of ongoing research. As Olssen and Hansen (2010) point out in discussing approaches to flexibility during the construction stage of a project, there are likely to be at least two views on flexibility on every project – one held by those who will use or run the building (client/users) and one by those responsible for financing and procuring the project. Also as health service and facility managers, and other key personnel change over the effective life of a facility, an early focus on facility-related flexibility initiatives may be lost as a result of poor knowledge transference, or alternatively, result in an emphasis on other priorities over time. Given these competing demands, for flexibility to be incorporated into the planning of a facility, built in to the finished facility and then used to future proof the facility during subsequent upgrades and refits, suggests that there has to be strong and unwavering organisational commitment to flexibility initiatives especially when faced with other competing project needs, and indeed changing personnel over time. The US Veterans Affairs Hospital Building System has demonstrated such commitment for nearly 40 years. Similarly the Westmead Hospital case study also shows the value derived from built in flexibility initiatives some of which have been utilized in ways perhaps not originally envisioned by those designing the building.

Lessons for other countries and settings include an overview of the difficulties associated with assessing the longer term flexibility and adaptability of health facilities. The primary focus of all health buildings is to support the delivery of health services; they are a 'tool' not a product in themselves. Similar drivers in most developed countries require changes in service delivery associated with new technology, evolving demographics, etc, to be accommodated. This research found that the assumptions behind the original case study flexibility strategies have been quite often superseded by emerging trends and events such as the move away from providing inpatient beds towards care in the community. However although such facilities were called on to

change and adapt for different reasons than those previously foreseen, they were still often up to this challenge.

Where future proofing features were documented and valued by the facility and other management, then the subsequent modification and upgrade of such buildings was more effective and efficient – and led to a longer effective life for the facility. Where these features were not appreciated or the relevant knowledge was not effectively transferred, facilities were more likely to become obsolescent. In particular, multi-storey or tower and podium type facilities appear to be least flexible and as a result, further research could be targeted at looking at how much flexibility is indeed enough or how to design multi-storey hospital buildings (such as POWH and RNSH) to flex and adapt over time. Given the cost and relative shortage of inner urban land, this may be a useful exercise to ensure that these buildings in particular may have a longer life than they have at present and would contribute to a more sustainable built environment in terms of future carbon and energy costs.

Acknowledgements: The authors wishes to acknowledge Health Infrastructure NSW in particular Bruce Judd, Robert Rust and Stuart Bosel for funding this research; and Michael Wong, Research Assistant, UNSW for providing support to the project.

REFERENCES

- Australia. Hospitals & Health Services Commission, & Sax, S. (1974). *A report on hospitals in Australia / prepared by Hospitals and Health Services Commission*. Canberra: Hospitals and Health Services Commission.
- Bjørberg, S., & Verweij, M. (2009). Life-cycle economics: cost, functionality and adaptability. In B. Rechel, S. Wright, N. Edwards, B. Dowdeswell & M. McKee (Eds.), *Investing in Hospitals of the Future* (pp. 145 - 166). Copenhagen: World Health Organization.
- Builder NSW. (1984). Mt Druitt Hospital. *Builder NSW*, 18-30.
- Burgmann, J. B. (1982). Fast-track at Westmead Hospital. *The Engineering Conference*, 246-252
- Carthey, J., Chow, V., Jung, Y.-M., & Mills, S. (2009a). *Annotated Bibliography*. Sydney: Centre for Health Assets Australasia (CHAA), Built Environment, University of New South Wales.
- Carthey, J., Chow, V., Jung, Y.-M., & Mills, S. (2009b). *Flexibility and Adaptability Report: An International Review for the NSW Context*. Sydney: Centre for Health Assets Australasia (CHAA), Built Environment, University of New South Wales.
- Carthey, J., Chow, V., Jung, Y.-M., & Mills, S. (2010). *Achieving Flexible & Adaptable Healthcare Facilities - findings from a systematic literature review*. Paper presented at the Health and Care Infrastructure Research and Innovation Centre (HaCIRIC) 3rd Annual Conference: Better Healthcare Through Better Infrastructure.
- Carthey, J., Chow, V., & Wong, M. (2010). *Health Infrastructure Future Directions: Flexible and Adaptable Hospitals - Lessons from Selected NSW Case Studies to Inform Future Health Projects*. Sydney: Centre for Health Assets Australasia, UNSW.
- Carthey, R., Ryan, A., Cameron, R., & Driscoll, S. (2007). *Concept master plan for Blacktown campus for Sydney West Area Health Service*. Australia: Aurora Projects Pty Ltd.
- Constructional Review. (1992). Survey 2: Children's Hospital. *Constructional Review*, 4-4.
- de Neufville, R., Lee, Y. S., & Scholtes, S. (2008). *Flexibility in Hospital Infrastructure Design*. Paper presented at the IEEE Conference on Infrastructure Systems
- Department of Health Gateway Reviews Estates & Facilities Division. (2010). Health Building Note 00-03 - 'Clinical and clinical support spaces'.
- Department of Veterans Affairs, Office of Facilities Management,. (2006). *Supplement to VA Hospital Building System Research Study Report*. Washington, DC.
- Dept of Veterans Affairs, Office of Construction. (1972). *VA Hospital Building System: Application of the Principles of Systems Integration to the Design of VA Hospital Facilities: Research Study Report Project Number 99-R047*. Washington, DC: Department of Veteran Affairs.
- Diamond, S. (2006). *R&D Project B(01)16: Rethinking hospital design - A research study commissioned by NHS Estates*: Department of Health.
- Health Services Development Unit. (2010). *Blacktown Mount Druitt Hospital Clinical Services Plan - Draft*. Sydney: Sydney West Area Health Service.
- Heath, T. (1984). Australia. *The Third Annual Review of Recent World Architecture, September 1984*, 188.

- Kendall, S. (2005). *Open Building: An Architectural management paradigm for Hospital Architecture*. Paper presented at the CIB W096 Architectural Management.
- Leighton Holdings. (2010a). Royal North Shore Hospital Redevelopment. *Projects* Retrieved 26 October, 2010, from http://www.leighton.com.au/about_us/projects/royal_north_shore_hospital_redevelopment.html
- Leighton Holdings. (2010b). Westmead Hospital Redevelopment Stage 1. Retrieved 4 October, 2010, from http://www.leighton.com.au/about_us/projects/westmead_hospital_redevelopment_stage_1.html/location/87/section/42513/p/38
- Nedin, P. (2011, April). The long game. *World Health Design: Essays in Sustainable Healthcare Design*, 4, 22-25.
- Nield, L. (2008). Changing hospital design in Australia. In S. Prasad (Ed.), *Changing Hospital Architecture* (pp. 223-250). London: RIBA Enterprises Ltd.
- NSW Health. (2010). Blacktown Hospital. Retrieved 7 October, 2010, from <http://www.wsahs.nsw.gov.au/blacktown/index.htm>
- Olszen, N. O. E., & Hansen, G. K. (2010). Identification of Critical Factors Affecting Flexibility in Hospital Construction Projects. [research]. *Health Environments Research and Design Journal*, 3(2), 20.
- Pati, D., Harvey, T., & Cason, C. (2008). Inpatient Unit Flexibility: Design Characteristics of a Successful Flexible Unit. *Environment and Behavior*, 40(2), 205-232.
- Prasad, S. (2011, April). Emergency Response. *World Health Design: Essays in Sustainable Healthcare Design*, 4, 6-9.
- Project Planning Team - Blacktown/Mt Druitt Hospitals Redevelopment. (1996a). *Project Definition Plan Volume One*. Sydney: Western Sydney Area Health Service - Blacktown/Mt Druitt Health Service.
- Project Planning Team - Blacktown/Mt Druitt Hospitals Redevelopment. (1996b). *Project Definition Plan Volume Two*. Sydney: Western Sydney Area Health Service - Blacktown/Mt Druitt Health Service.
- Randwick City Council. (2010). Randwick Education and Health Specialised Centre Discussion Paper - Summary Document for Public Consultation. In Randwick City Council (Ed.). Sydney: Randwick City Council.
- Wislocki, P. (1996). No worries at Westmead. *World Architecture*, 62-65.