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Flexibility and Adaptability Report: An International Review for the NSW Context

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CENTRE FOR HEALTH ASSETS AUSTRALASIA

Health Infrastructure, NSW Health
Future Directions Project

FLEXIBILITY AND ADAPTABILITY REPORT:
An International Review for the NSW Context

UNSW THE UNIVERSITY OF NEW SOUTH WALES | BUILT ENVIRONMENT

HEALTH INFRASTRUCTURE NSW HEALTH

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1.0 Introduction

1.1 Background

Health Infrastructure NSW is investigating topics that will guide the design and delivery of health built infrastructure in NSW for the next 20 to 30 years. Topics that will influence design and delivery include:

- Masterplanning that will impact guidelines on emerging directions for planning of healthcare assets
- Flexibility and adaptability requirements that will impact cost-effective ways to future-proof health assets
- Capital Programme options that will examine opportunities to extract greater value from State investment.

This report outlines the findings of the Centre for Health Assets Australasia (CHAA) resulting from the investigation of the second topic. The study comprised a literature review looking at flexibility and adaptability from an international perspective, with a particular emphasis on cost-effective ways of future-proofing health assets. The scale of the study ranged from site masterplanning level to the building envelope.

1.2 The Need for Flexibility and Adaptability of Health Facilities

It is recognised that rapidly changing demands are being placed upon healthcare infrastructure and the difficulties in accommodating this in the current approaches to design and construction of many contemporary health buildings. This lack of flexibility and adaptability often leads to early obsolescence and the need for expensive replacement or upgrade of facilities.

Flexibility and adaptability may be defined in terms of their impact on different aspects of the procurement process, the level of impact they have upon the built form (from urban scale to detailed design) and how they affect day to day operation of the facility. For example, some manifestations of flexibility and adaptability require only minimal manipulation of the immediate working environment such as moving furniture or equipment, whilst others require greater intervention e.g. moving walls, extending or renovating space for different functions and purposes.

This report considers practical *built form* implications of implementing strategies aiding flexibility and adaptability in terms such as those defined above. It is generally limited to discussing flexible strategies that have an applicable design outcome.

1.3 Assumptions and Exclusions

The study assumed the need for a practical and outcomes focused report that provided guidance and directions regarding possible initiatives that could either be implemented on NSW hospital projects or where necessary, investigated further by Health Infrastructure NSW. To that end the conclusions of the report include recommendations for further areas of research.

The study generally excluded but also touched incidentally on the other issues of interest to Health Infrastructure NSW that would be included in an all embracing report. These are listed below and some were of more relevance than others and thus investigated in greater depth or detail.

- Models of Care - What are the emerging trends in Models of Care and how do they affect the way healthcare facilities are built?
- ICT - How might ICT change the way healthcare services are delivered and how should healthcare assets adapt in response?
- Patient Safety - How can the design of healthcare assets be used to improve patient safety?
- Environment - TS11 currently sets certain environmental standards for healthcare assets. What are the most cost effective ways these standards can be met? How might the standards change in the near future?
- Affordability - How can health facilities be procured with a reduced dependence on state investment plus associated stimulation of private investment?
- Policy - How will current and anticipated State and Federal policy impact on facility planning and procurement, in particular the recommendations NSW Health accepted from the Garling Report?

The study has focused on case studies mostly drawn from overseas countries although one or more Australian case studies are also noted. In general, it has attempted to source these case studies from health systems that are roughly similar to the Australian system especially those with an emphasis on universal health insurance. The chosen case studies were also preferably to be drawn from systems that include a mix of public and private healthcare provision rather than from systems focused on 'for-profit' healthcare or that spend much greater proportions of GDP on healthcare, such as the USA. However, ultimately it was not possible to exclude all information from the US context, as due to population size and overall quantum of health expenditure, there are many more health facilities designed and delivered in that country with opportunities for learning from this body of work. The study found that there is also significant interest in the issues of flexible and adaptable health facility design within the US and this occurs at a range of levels. As a result there is available a substantial quantum of publications reporting relevant research which often includes examples of projects incorporating the study principles. Therefore it was concluded by the study team, that it would not be wise to ignore this significant body of information without at least considering lessons learnt that could be applicable across other health systems, even those with apparently widely disparate funding levels and sources.

1.4 Structure of this report

This report is a practical guide to hospital design in the Australian context. It is intended for the Health Infrastructure (HI) Committee; and more broadly for HI personnel in particular, industry consultants including designers and other interested personnel. It summarises trends and findings identified from the main body of research which comprised a comprehensive literature review into the area of flexible and adaptable healthcare buildings with a focus on the international context and relevant case studies.

The main research output from the literature search is an annotated literature review which reports and categorises the range of literature found ranging from the academic to the project level. Information was sought from diverse publications such as books, academic journals, trade journals, website reports, government policy directives, reports from professional colleges and associations, newspapers (where available) and other sources. As noted above, particular emphasis was placed on sourcing information regarding international trends in healthcare infrastructure projects especially from countries with a similar health system, comparable expenditure on health services delivery and preferably also with a reputation for innovative design and project delivery. 'Similar health systems' included those with a similar geographic spread and funding mechanisms as applies in NSW.

The report has been structured to accommodate the needs of different readers and the varying levels of detail that they wish to derive from the report. It should be read in conjunction with the companion volume which sets out the results of the literature review as an annotated bibliography.

2.0 Methods for Systematic Review

2.1 Systematic review

A systematic literature review aims to 'find and evaluate the best available research on a specific question' (Campbell Collaboration, 2009). The method evolved as a reaction against more traditional literature reviews which appeared to lack rigour and not be conducted in accordance with a scientific method. Traditional reviews have tended to be an ad hoc collection of past research and are often subjective in nature, reflecting the bias and idiosyncrasy of the individual reviewers (Ballard & Rybkowski, 2007). As a result, there has been general recognition of the need to upgrade the standard for literature reviews (Mullen & Ramirez, 2006).

Systematic reviews are scientific investigations with pre-planned methods. They use strategies that include a comprehensive search of all potentially relevant articles and the use of explicit, reproducible criteria in the selection of articles for review (Cook, Mulrow, & Haynes, 1997). Systematic reviews use transparent procedures that are defined in advance in order to ensure transparency and minimise bias. Core elements for a systematic review include an explicit search strategy, clear inclusion/ exclusion criteria, systematic coding and analysis of included studies (Campbell Collaboration, 2009). In addition to minimising bias, systematic reviews are seen to have many advantages in terms of efficient management of information, provision of data for rational decision making, consistency and generalisation of the findings, and improvement of reliability and accuracy of conclusions (Mulrow, 1994).

This study has been completed through the use of a systematic literature review.

2.2 Research question and refinement strategy

The research question initially developed for this research was

How can we design health facilities for flexibility and adaptability? Can we discover cost effective ways to do this, drawing on examples from a mainly international perspective from health systems similar to the Australian system (and NSW in particular)?

To answer this question, the research question was refined into an operational format that could be researched systematically. Development of a clear search frame was essential to ensure relevant and meaningful outcomes during the refinement of the research question. The method for the formulation of a research question will usually vary according to topic and research area. Some protocols for systematic review in healthcare research suggest four basic components are required in terms of presenting the reported research. These are usually: 1) type of person involved, 2) type of intervention that the person experiences, 3) type of control in which the intervention is compared, and 4) the outcomes to be anticipated (Counsell, 1997). Other protocols recommend a five part strategy be adopted that comprises 1) problem, 2) intervention, 3) outcome, 4) comparison, and 5) target population (Bridge & Phibbs, 2003).

Notwithstanding the protocol adopted, the strategy or process must be detailed in order to allow replication by other researchers. However, as the topic of this research was the design of healthcare environments, without specific consideration of clinical interventions to a patient population, this research adopted a simpler three part strategy or protocol covering 1) environment, 2) intervention, and 3) outcome.

The most important aim for a search strategy is ensuring that all the important and relevant information is covered. To do this, selection of proper search terms is critically important. For this study, the list of keywords and relevant synonyms were developed from preliminary study and trial searches through electronic databases.

The actual search was conducted using combinations of the following words:

Environment	***Intervention***	***Outcome***
Hospital	Design	Sustainability
Health care facility	Architecture	Flexibility
Healthcare facility	Construction	Adaptability
Health infrastructure	ICT (Information and communication technology)	Open building
Health facility	Technology	Future-proof
Medical facility	Innovation	Future
	User demands	Expandability
	Model of care	Change
	Whole life	
	Masterplanning	
	Additions	
	Usability	
	Cost-effectiveness	
	Life cycle	
	Efficiency	

Table 1 - Research Search Terms

2.3 Search strategy

Inclusion & exclusion criteria

Inclusion criteria can be set relatively narrowly or more broadly. However, either way of defining inclusion criteria has risks. Narrowly defined inclusion criteria can limit the amount of data to be found which increases the risk of false conclusions being drawn. More broadly defined inclusion criteria increase the amount of data found, yet also increases the risk of heterogeneity and potentially significant variations in the results of the search. This can make analysis difficult (Counsell, 1997). Ideally, inclusion/exclusion criteria are defined prior to data collection and not changed during the course of the search. However, it is common for the criteria to be reasonably flexible in order to

permit some changes based on the amount of data found including the relevance to the research question being asked.

For this study, all materials that included the above keywords and search terms were considered to be potentially relevant. However, the following exclusion criteria were also established to ensure that the results found had the best chance of being useful for the study. This systematic review particularly sought information that provides practical implications for flexible and adaptable design of healthcare facilities, based on real life case studies. Therefore, those publications that did not include detailed design features, or that simply endorsed the necessity and principles for flexible design without any detail given, or those that rhetorically described or praised a building using flexibility-related terms were deemed less relevant. Other exclusion criteria included:

- Publications on buildings other than medical facilities such as hotel and residential housing.
- Publications without design implications, such as: a focus on construction materials, a narrow study of energy use, for example electricity and water; or the reuse of a former hospital for housing or other uses.
- 'Glossy' architectural publications such as pamphlets and trade magazine that were considered unlikely to have much depth beyond editorial or advertorial content.
- Articles written in a language other than English.
- Research and reports published pre 1990, which were not deemed to provide useful information to current practice.
- Publications from countries with dissimilar practice or very different cultures: Eastern Europe, Asia, Middle East, etc.
- Publications with relevant terms but used out of context, for example some publications resulting from the following keyword searches were excluded for the following reasons:
    - *'Design'* - the aim was to find publications on flexible design. However search results were very broad as 'design' can relate to the design of medical equipment or workplace schedules. Where such studies had no facility design implications they were excluded.
    - *'Sustainability'*- this was searched in the context of a building being 'sustainable' in terms of its use now and into the future; however, the search results mainly focused on environmentally sustainable design issues such as the selection of environmentally-friendly material or the prevention of outflow of toxic and medical waste. Whilst an important consideration of design, these issues were considered outside the scope of this study and were hence excluded.

Identification of publications

To identify relevant publications, a comprehensive list of potential sources was considered. The first and most commonly used strategy adopted for finding these sources was the searching of electronic databases. Given the wide range of potentially relevant databases available, those most likely to be relevant to the research question were determined. For this study, electronic databases covering the topics areas of architecture, engineering, health, business and science disciplines were selected. In addition to searching using standard online electronic databases, a Google search and Google Scholar search were conducted. Use of this range of search engines provided scholarly literature including

peer-reviewed articles, theses, books, abstracts and technical reports from a range of knowledge backgrounds.

Although a considerable number of available resources were found using the electronic database and Google searches, it was recognized that potentially relevant articles in journals or other sources not indexed in the databases searched would not be identified. Therefore, further search methods were employed to overcome this issue including manual searching of journals, trade magazines, conference proceedings, books, reference lists from similar projects, and other existing study registries held by CHAA and associated research bodies. In particular, the collection of material held by the CHAA library was searched including all books, journals, EndNote databases, and the bibliographies of all papers published by CHAA. Conversations were initiated with Australian and overseas research and professional colleagues via email or telephone.

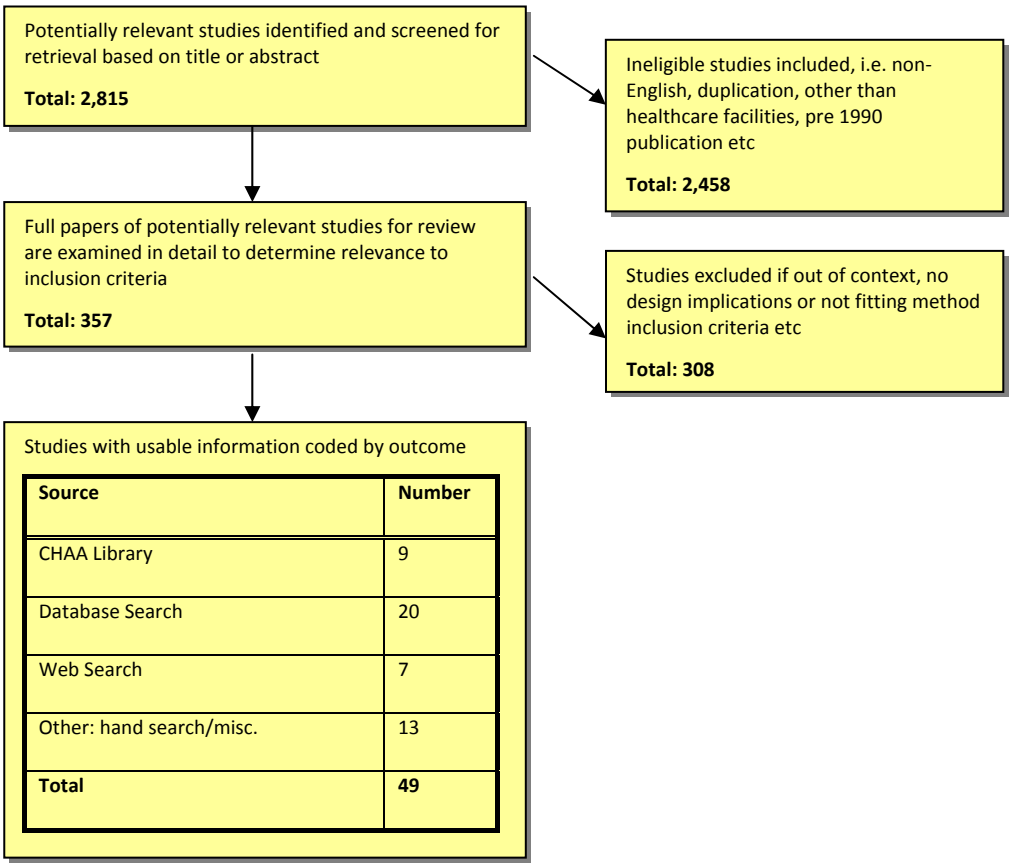
Finally, to maximize the coverage of the search, publications located beyond the University of New South Wales library services were also sought through inter-library loan services. Following is a list of the sources which yielded relevant studies for further investigation by the study:

- Centre for Health Assets Australasia (CHAA) Library
- Standard electronic databases:
  - ARCH: Australian Architecture Database
  - Avery Index to Architectural Periodicals
  - MEDLINE
  - ICONDA
  - BUILD: Australian Building Construction and Engineering Database
  - Compendex
  - ENGINE: Australian Engineering Database
  - Scopus
  - RIBA Library (Royal Institute of British Architects Library)
  - Web of Science
  - AMI: Australasian Medical Index
  - Business Source Premier
  - Academic Research Library
  - APAIS: Australian Public Affairs Information Service
  - ABI/Inform global
- Web: Google / Google Scholar
- Others: manual searching, reference lists, personal contacts with colleagues and researchers, etc.

A complete list of operators and truncation symbols used for this report is included in Appendix 2 - Operators and Truncation Symbols.

2.4. Review process

All material retrieved from these sources were judged against the inclusion and exclusion criteria. Initially the titles and abstracts of all material recovered were assessed. If they were deemed to be relevant to the research question and met the inclusion/exclusion criteria, the full text of the article was sought. Finally the full text were fully reviewed and judged as to the relevance to the inclusion criteria. This research finally included 49 publications for review as per the diagram below.



Source	Number
CHAA Library	9
Database Search	20
Web Search	7
Other: hand search/misc.	13
Total	**49**

Figure 1 - Search Results - Refinement

3.0 Research outcomes

Material collected by this review falls broadly under three main categories:

1) *Case study based studies* that provide detailed accounts of processes followed to achieve flexibility and adaptability, plus information regarding useful design features based on one or more actual case studies.
2) *Theory based studies* that explored concepts and principles of flexibility or adaptability based on accumulated knowledge and information from case study examples or derived from hypothetical projects such as the 'Fable Hospital'.
3) *Historical overviews* that examine past projects, usually using some form of literature review, summarising what has been learnt from the past and possible ways to move forward to the future.

Every reviewed publication has been coded in the literature review matrix. Articles reviewed have been tabulated according to nationality, types of facilities, context of the study focus, and methodologies employed for the study (see Appendix 1 - List of Major Case Studies). The matrix organises the literature, and enables assessment of it in terms of general characteristics including identifiable themes. See Appendix 3 - Literature Review Matrix.

3.1 Nationality

The nationality of the research publication has been coded based on the place where the research was conducted. Generally, this also resulted in nationality coding based on the location of the healthcare facility(ies) being studied. However, there were situations where the place of a study was not clearly identified, or where multiple cases were used for a study. Therefore, it should be noted that the following figures do not exactly correlate with the number of case studies included in this review.

Almost half (48%) of the publications included in this review are based on healthcare facilities located in the USA or result from research conducted in that country. This suggests that although the USA may appear to be the leading country in the implementation of flexible healthcare facility design, this may also perhaps simply be the result of the larger overall volume of projects and published research undertaken in that country. The United Kingdom accounted for the second largest proportion (18%) of publications, followed by Norway (7%). Whilst flexibility was also the subject of study in many of the European countries, the number of research studies found per country was relatively smaller than the number produced by the USA or the UK.

These findings are perhaps not surprising, firstly given the size of the US economy, its population and healthcare budget. Secondly, where European countries do not routinely publish research studies in English, their research into this area of design may have been overlooked by the study and would thus be underrepresented in the studies found.

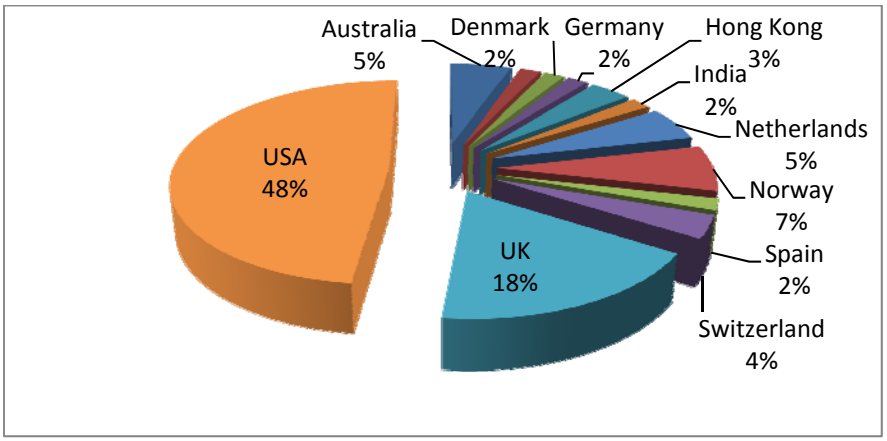


Figure 2 - Sources of Research Studies

3.2 Type of facilities

Most of the literature (73%) discussed flexibility in designing 'hospitals.' This is unsurprising as hospitals have played a central part in providing clinical care services. However, some studies paid attention to the potentially increasing role of 'ambulatory care centre' and 'primary care centre' in healthcare delivery. Greater emphasis has been placed on preventative and ambulatory care as care delivery changes (Farrelly, 2002) and there has been recognition of the benefits from an enhanced range of primary care services in the community rather than in an acute hospital (Potter, 2008). The studies reviewed suggested that these buildings are often designed to be flexible and adaptable enough to respond to new demands.

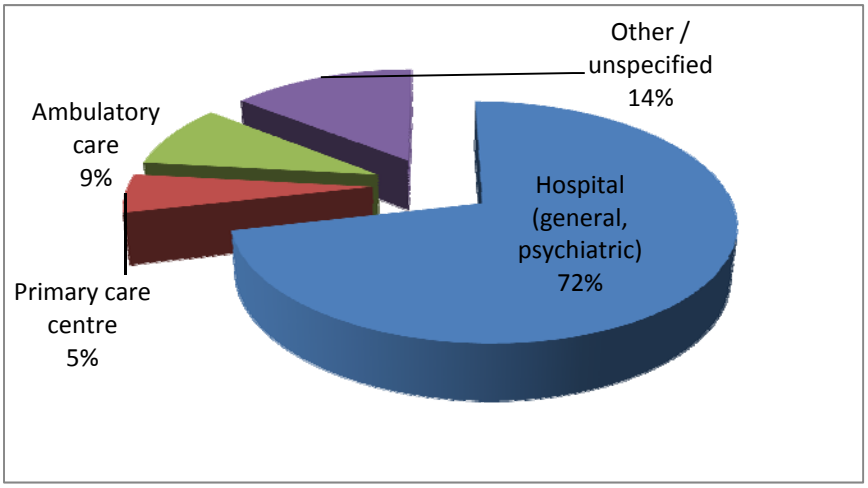


Figure 3 - Types of Facilities Studied

3.3 Stages of flexible design

A strategy of flexible design can be applied to a specific stage of the building process and lifecycle of the building. As a whole, healthcare building projects can be divided into five stages:

1. Funding and tendering
2. Site masterplanning
3. Building design
4. Construction
5. Facility management.

While flexible design should be considered at every stage of the project cycle, the largest (44%) amount of interest in flexible design was given to the 'designing stage.'

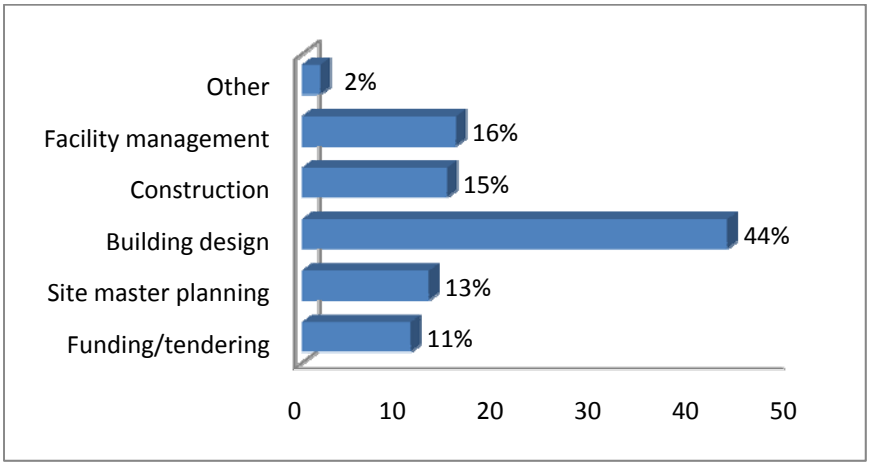


Figure 4 - Stages of Building Projects Studied

3.4 Contexts of flexible design

Flexible design is motivated by a range of concerns and needs. Literature reviewed in this study focused on various contexts for flexible design. The ever changing 'model of care' (38%) was identified as the biggest driving force for flexible design in healthcare facilities. Other contexts for flexible design included 'affordability & long term cost-efficiency' in managing facilities (18%), 'patient safety' (17%), and accommodation of new 'information and communication technologies' (15%).

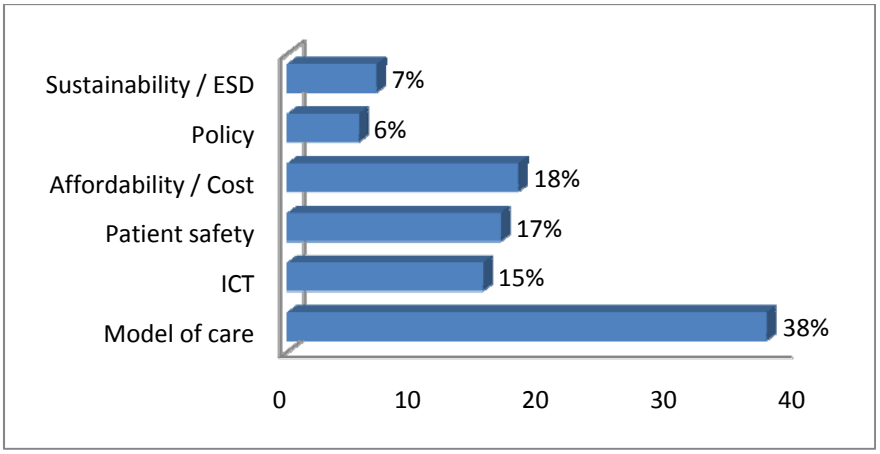


Figure 5 - Contexts and Drivers for Flexible Design

3.5 Methods

The following figure depicts the methodologies used in the 49 sources included in this review. The largest percentage of sources (61%) based their work on actual 'cases', with the next most common methodology used being the seeking of 'expert opinion' (24%) from architects and academics. Therefore, the outcomes of this review are strongly based on empirical real life examples of flexible design.

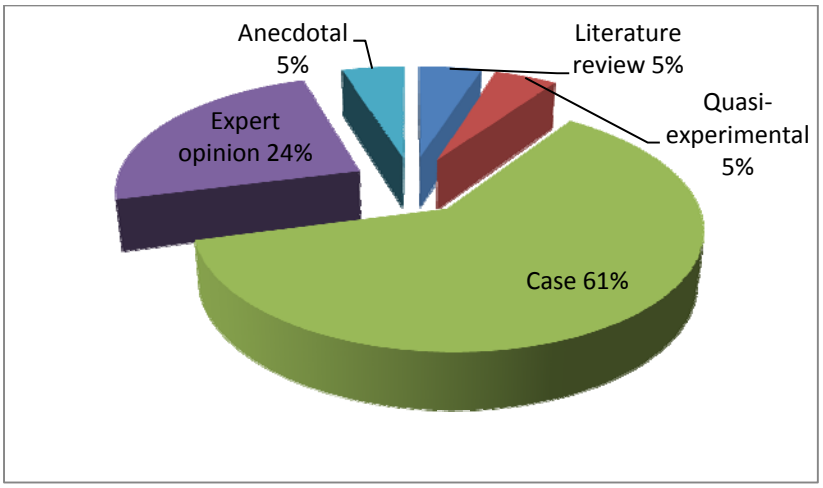


Figure 6 - Methodologies Used in Sources

3.6 Case studies identified

This review has identified 19 existing healthcare facilities that have been designed and built using the principles of flexibility and adaptability (see Appendix 1 - List of Major Case Studies). These case studies were deemed to be useful to further the discussion of flexible design. They were included in this review for the following reasons:

1) The case has been documented with objective, quantitative data by at least one source, with the understanding that further information, including architectural drawings, may be searched for at a later stage.
2) There is analysis and assessment, supported by evidence, as to whether the project has been successful or not, and how one might learn from it.
3) The measures employed and claimed to be 'flexible' are beyond the conventional measures that would be employed on any project, regardless of the need for flexibility.
4) The 'flexible' measures have design implications.

Some sources identified that they discussed data from some anonymous case studies and, on occasion, gained classified insider information from personnel who were involved with the project (for example, see Barlow & Koberle-Gaiser, 2009a). Such case studies are discussed throughout both the research studies, and this report without reference to their true identity.

4.0 Designing for Flexibility

4.1 Defining 'flexibility': Beyond the Buzzword

The term 'flexibility' has been used in numerous contexts to describe anything from flexibility of staffing needs which carries with it design implications (see for example Harvey & Pati, 2008; Vos, Groothuis, & van Merode, 2007) to flexibility in the masterplan to cater for future renovations and expansions (see for example Lam, 2007a, 2007b; Westlake Jr, 1995). The need to design for potential change is widely acknowledged, but terms such as flexibility and adaptability are used loosely and often interchangeably, leading to a general vagueness causing loss to much of their value (Worthington, 2008). The definitions themselves are also contested - for example, Worthington defines flexibility as a subset of adaptability, whereas Pati et al (2008) identifies adaptability, convertibility and expandability all as subsets of flexibility. Still others avoid defining these elusive terms altogether by focusing discussion instead on building or design elements affected by change.

Much of the problem in defining these terms is due to 'flexibility' not being something that can be designed, rather it is something to design *for*; and whilst it can be applied as a descriptor to many things, it has little meaning by itself. It is essential to understand that designing for flexibility is not a static concept but one that needs to be incorporated on many levels of a project to form an organized system (see Odegard & Justison, 1996 for a step-by-step approach). The following table shows some of the ways recent researchers have attempted to define the term when considering healthcare assets. The authors of this report note the abundance of often conflicting definitions and hence, for consistency, use the terms as defined below throughout this report.

Focus	Managerial considerations	Functional requirement	Building system
Micro ↓	***Operational*** Easy to reconfigure, low impact on time and cost (e.g. furniture and interior spaces)	***Adaptability*** Ability to adapt to operational changes e.g. workplace practices	***Tertiary*** 5-10 years lifespan, no structural implications e.g. furniture
	Tactical Involves commitment of capital expenditure; changes not easy to undo (e.g. design of operating theatres)	***Convertibility*** Ability to convert rooms to different functions	***Secondary*** 15-50 years lifespan, e.g. walls and ceilings
Macro	***Strategic*** Substantial increase in the lifetime of the infrastructure (e.g. long term expansion plans)	***Expandability*** Ability to expand the building envelope and specific hospital function	***Primary*** 50-100 years lifespan, e.g. building shell
Source	*(Neufville, Lee, & Scholtes, 2008)*	*(Pati, et al., 2008)*	*(Kendall, 2005b)*

Table 2 - Definitions of Flexibility and Associated Concepts

Although the focus differs, all the above definitions explore the application of flexibility in terms of categorising the macro and micro implications for projects and facilities. Diamond (2006) summarises these considerations in terms of time and scale as per the table below:

	Duration	***Potential conditions for indeterminate change***
Site	Timeless	Move from property assets to range of sites and building tenure to facilitate change and adaptability
Shell	5-50 years	Range of building types - temporary to permanent - to facilitate rapid indeterminate change
Services	3-15 years	Services highly accessible and potentially remote from building envelope for flexibility and mobility
Systems	1-5 years	Increasingly significant cost - near future technologies, unknown accessibility and mobility, spatial demand unknown - technological equipment may get smaller but trend towards increasing amounts
Settings	Day to day	Emphasis on 'shell and setting' buildings, reduction in fixed scenery with emphasis on mobility and adaptability

(Diamond, 2006) p.30

Table 3 - Time and Scale of Change for Different Facility Components

Further, 'flexibility' may be applied to different stages of the hospital procurement or project lifecycle, and the authors have identified the following stages for discussion:

- Funding/tendering stage - contracts are drawn and the initial brief prepared
- Masterplanning stage - design of the site and building envelope
- Building design stage - conceptual design and building layout
- Construction stage - detailed design and construction
- Operational stage - facilities management, periodical renovations and maintenance
- Conversion, renovation and decommission - i.e. what to do with the building at the end of its useful lifecycle.

These are reflected in the matrix and are explored in further detail in Section 5.0 of this report.

4.2 Emerging themes in hospital design flexibility

The literature reviewed identified a series of strategies that may be employed when planning for flexibility or adaptability of healthcare facilities. The practical applications of each are illustrated in the case studies noted below.

	Strategy	***Description***	***Application/rationale***	***Example Case Stud(ies)***	***Further Reading***
Room	Acuity-adaptable rooms	Instead of being specified for different level of acuity and treatment methods, rooms are standardised so that patients do not have to move around to receive the care they need.	Patient safety by reducing patient falls and prevention of 'bottle neck' at the critical care units	St Joseph's, WI; Methodist Hospital, IN; Clarian Health Partners, IN.	*(Scalise, Thrall, Haugh, & Runy, 2004), (Hendrich, Fay, & Sorrells, 2004)*
Building	Modular layout	A modular grid layout based on what can be accommodated within the space	Not designing each space for a single function allows opportunities for change later	Insel Hospital, Bern; John Stroger Jr. Hospital, Chicago	*(Diamond, 2006) (Jonassen, Klemenic, & Leinenwever, 2001) (Doiel & Loharikar, 2003)*
	Interstitial Floors	Inset service floors of at least 1.8m in height between each habitable floor	Universal wall-less cabling and servicing, freeing up the floor plan for future alterations	Rikshospitalet, Oslo; St Vincent's, Sydney	*(Scott, 1993) (Farrelly, 2002) (Verderber & Fine, 2000) (Valen & Larssen, 2006)*
	'Generic Clinic'	Clinics are not tied to individual building blocks but can be shared between blocks	Added operational flexibility responding to patient demand and staff logistics	St Olavs, Trondheim	*(Jensø & Haugen, 2005) (Valen & Larssen, 2006)*
	Discrete building systems	Main structure / building shell to remain separate from internal partitions	Interior renovations and changes to room layouts would not affect the main structure and hence are easier to implement	Insel Hospital, Bern	*(Kendall, 2005b) (Geiser, 2004)*
Site	'Empty Chair'	The masterplan allows one part of the site to always remain undeveloped throughout the hospital infrastructure lifecycle. As one vacant site is developed for a new project, the next site should be identified and preserved for future use	Always having dedicated additional area on site means building upgrades or renovations cause less operational disruption and situations of inappropriate clustering or poor placement of buildings due to lack of space on site are prevented.	Martini Teaching Hospital, Groningen	*(Thiadens, Kriek, Afink, Burger, & Oosterom, 2009)*
	Land purchasing Option	Paying an option or otherwise securing land adjacent to the site in anticipation of future expansion	Provision of space for future horizontal expansion	Royal Victoria Infirmary, Newcastle-upon-Tyne, UK	*(Lee, 2007) (Neufville, et al., 2008)*

Table 4 - Strategies in planning for flexibility and adaptability of healthcare facilities

4.3 Historical development in designing for flexibility: the McMaster University Health Science Center case study

Although this research primarily focused on recent case studies, it should also be noted that many concepts that are covered were also pioneered in earlier healthcare facility projects such as those constructed during the 1960's and 1970's. A good case study example is the McMaster University Health Sciences Center, constructed in 1972, which included numerous flexible design considerations:

- ***Interstitial floors*** for servicing were inserted between each primary floor for human circulation, thus freeing up the primary floors of many structural, mechanical and electrical requirements and enabling flexible floor plans.
- ***Discrete building systems*** were created separating the building into permanent and non-permanent elements, with the permanent building shell containing electrical and mechanical services that various functions can plug in to.
- ***Future expansion*** was comprehensively planned for, with a structure that can support additional loading and vertical shafts extending beyond the existing uppermost floor in anticipation of an additional floor.

Unfortunately these design options were never realised. Due to changes in hospital administration and political and economic conditions, subsequent plans for expansion resulted in a new, off-site building being built instead, and the hospital itself remained unaltered from the time of its original completion (The American Institute of Architects, 2005). Furthermore, by 1980, the trend towards the use of interstitial floors, which had been embraced and widely adopted in America and Europe during the 1960's and 1970's had ceased, due to the high initial building costs and the inability to prove significant future savings can be made (Verderber & Fine, 2000).

Locally, NSW hospitals such as Westmead Hospital built in the 1970's and the New Children's Hospital at Westmead completed in the 1990's also aimed at incorporating flexibility and adaptability strategies to ensure that future growth, change or even downsizing of these facilities could be addressed. Various local case studies have been discussed by Lawrence Neild (2008a) including Westmead, Mount Druitt, Blacktown Hospitals and others. These facilities could be the focus of future local research regarding the success or otherwise of incorporating flexibility and adaptability principles into past projects built in NSW and in other parts of Australia and New Zealand.

Since the 1970's, in the UK at least, design focus has been on refining economies of scale, predictability in cost, and quality control (Barlow & Koberle-Gaiser, 2009a). The development of more sophisticated financial analysis models prompted by the recent renewed interest in flexible design should benefit from past experiences such as the McMaster case study and local case studies of even greater relevance to the NSW context. Some of the costs and benefits of implementing flexibility measures are outlined below, to provide an overview of how they may be planned for in new health infrastructure and the decision making processes involved.

4.4 Costs and benefits of implementing flexibility measures

Flexibility can be viewed as providing options for the future, without the obligation to exercise those options (Neufville, et al., 2008). Examples might include designing additional loading to the structure or bigger rooms than currently required in anticipation of future development and extensions, such as the acuity-adaptable universal room concept. The incorporation of these options may or may not have capital and/or operational costs associated with their implementation, but this needs to be viewed in context of the building's lifecycle costs. From the literature reviewed, it seems reasonable to conclude that the additional initial costs associated with designing for flexibility can often be justified by both qualitative and quantitative benefits in the future (see Eagle, 2006; Eagle, 2007; and Pressler, 2006 for case study examples).

Many recent authors encourage the adoption of a lifecycle approach to the cost-benefit analysis of healthcare assets, as the initial investment forms only a small part of overall costs of a project. Specifically, Valen & Larssen (2006) have shown that total construction costs are quickly exceeded by between two and three years of total operational costs. Bjørberg & Verweij (2009) classified life-long expenses into lifetime costs and annual costs, and showed through a case study that choosing a development option minimising initial construction costs does not necessarily yield better return overall. This conclusion is also reached in a hypothetical business case scenario in an article by Sadler, et al. (2006) - the 'Fable Hospital', although Sadler and his colleagues calculated additional construction costs only, without taking into consideration that bigger rooms may lead to possibly higher operational costs due to longer walking distances for staff and other similar issues.

Taken holistically for example, a focus on patient safety could lead to other savings such as reduced patient falls and medical errors (Hendrich, et al., 2004) or increased patient satisfaction (Bush, Reisman, Anstine, Gallaher, & Davis, 2005). A case in point, the Cardiac Comprehensive Critical Care department at Clarian Health, Indianapolis in the USA experienced a 70% reduction in medication errors, 90% reduction in patient transport and achieved a national benchmark of 2 falls per 1000 patient days (Hendrich, et al., 2004).

Flexibility options should not be considered in lieu of other client objectives and they in fact can co-exist successfully alongside each other. When briefing consultants, clients need to emphasis whether the goal is to focus on patient safety (see Datta, 2000), patient-focused care (see Jensø & Haugen, 2005) or the humane hospital (see Reiling, et al., 2004) for example, and from there can decide what range of flexibility measures may be appropriate inclusions.

When planning for an adaptable building, multiple scenarios should be considered in order to understand possible design outcomes rather than simply relying on an estimate relating to only one example of likely future use or point estimate (Odegard & Justison, 1996). An example of the point estimate method is to predict a city's future population based on the current analysis of demographic trends and as a result, design the size of the hospital according to that current prediction only - this is a linear process. Using multiple scenarios, including likely operational requirements, healthcare design consultants should be challenged to create a physical environment that can satisfy a range of potentially foreseeable (and high priority) outcomes, rather than responding to only one selective scenario, no matter how compelling that may currently appear based on contemporary priorities,

limited capital budget or service demand calculations (Neufville, et al., 2008). In the case noted above, a range of possible population scenarios should be considered and to respond, a flexibly sized hospital could be designed to respond to a range of demographic outcomes (scenarios) rather than to the single prediction. The likely scenarios thus identified should then inform the brief that the architects and other design consultants work from, noting also that a good design should provide an adequate amount of flexibility, but no more than that (Pressler, 2006).

5.0 Implementation: considerations at each project phase

Section 5 sets out the aspects to be looked at for each stage of the project in order to successfully implement the flexibility strategies discussed in Section 4.0. Whilst flexibility measures have been categorised into project stages in this section, it should be noted they must not be considered in isolation from each other.

5.1 Funding/tendering stage

As noted by Worthington (2008), "the biggest opportunities for success can be won, or lost, in the briefing stages of a project". The briefing stage actually begins before the consultants are engaged, at the tendering and bidding stage, when the client decides what should be included in the contract.

Traditionally, in Australia, the majority of hospitals have been publicly funded and operated, however recently many European countries are moving away from this 'risk-free' investment environment and creating a separation between bodies responsible for investment funding and operational expenditure. This is believed to be creating incentives to emphasise the building's performance over its entire lifecycle and provide flexibility to cope with a volatile and shifting environment (Bjørberg & Verweij, 2009).

On the other hand, the UK has put into operation Private Finance Initiatives (PFI), and specifically it has been used exclusively in England since 1997. A PFI scheme is a model of Public Private Partnerships (PPP) where the private-sector consortium - the 'special purpose vehicle' (SPV) enters into a contract with the public-sector to deliver and operate the hospital infrastructure for a fixed period (Barlow & Koberle-Gaiser, 2009a). As Australia is following aspects of the UK model, and has already implemented this approach or variations of it, on several projects, it is timely to reflect on recent studies of UK's PFI system to investigate how it aids or hinders flexibility in hospital design.

Avoiding common pitfalls of PFI

The bidding process in the UK system of Private Finance Initiatives (PFI) has been criticised for the way it "stifles innovation" (Barlow & Koberle-Gaiser, 2009a), as it is fiercely competitive and bidders are often asked to respond to generic statements calling for a flexible and adaptable building without specific requirements. This leads to designs that meet only minimal requirements with the primary goal being to win the bid. Further, under the existing UK PFI scheme, the SPV receives a fixed annual income, unencumbered by risks arising from technical obsolescence, changing regulations and policies, or other unidentified future healthcare needs. These risks all remain with the public sector. Hence the SPV is not incentivised to think creatively to combat future adaptability issues (Neufville, et al., 2008).

Learning from the UK experience a few major points could be made as follows:

- Consider the newer 'smart PFI' system where the design stage is separate from the subsequent tendering process (Barlow & Koberle-Gaiser, 2009a).

- Quantifiable measures for flexibility should also be a written condition of the PFI agreement (Neufville, et al., 2008); in particular, clients should consider employing mechanisms that incentivise quality and efficiency improvements during the operational phase (Barlow & Koberle-Gaiser, 2009a).
- Conduct rigorous financial analysis to formulate a specific, evidence-based brief as opposed to vague requirements such as "design for 25% extra capacity". This will support the economic case that the value of flexibility exceeds its initial costs (Neufville, et al., 2008).
- The sharing of risks needs to be re-examined in the PFI contract, moving away from the notion of a 'fee-for-service' relationship to a true partnership (Neufville, et al., 2008).
- A model for identifying risks has been developed by Lee (2007), which characterises 'operational', 'uncertain event' and 'flexibility in 'OUF Matrices'.

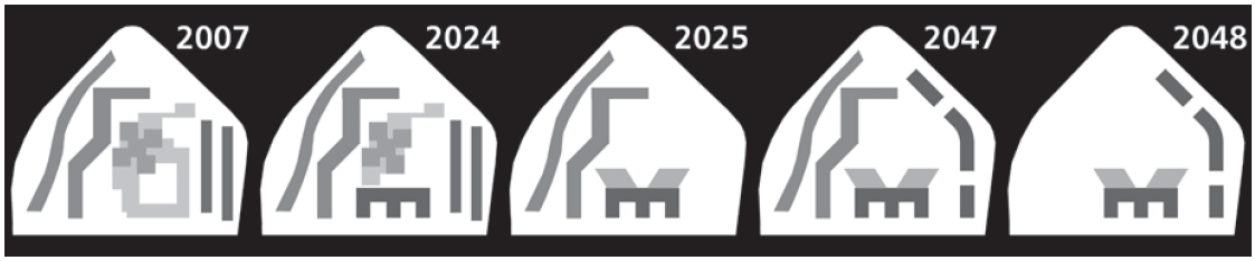
Other funding / design briefing models

A study based on anonymous case studies comparing UK hospitals to French hospitals concluded that French hospitals outperform UK hospitals, and stated that French hospitals benefit from a consultant-led approach. The study contends that even though the French case studies are equipped with all single bed wards built to a higher standard than those in the UK, the overall capital cost is between half to two thirds that of the UK hospitals. It was suggested that this is largely due to UK contracts being over-specified, whereas French contractors are able to employ simple and standardised construction methods and fittings (Building Design Partnership, 2004).

The privately funded Ohio State University Richard M. Ross Heart Hospital in Ohio, USA, benefited from the involvement of the hospital's planning committee consisting of over 50 members encompassing all interested parties (Bush, et al., 2005). The importance of engaging with hospital staff is also emphasised by Rechel et al. (2009) for the St Olavs Hospital in Trondheim, Norway.

5.2 Masterplanning

The masterplan must be developed in such a way that the hospital can move and grow over time with minimal disruptions to its operation. Due to its sensitive nature, renovations and extensions are extremely difficult and construction work within the hospital building itself is usually highly undesirable. The effects of masterplanning on overall performance is clearly shown in a study of six Norwegian hospitals with the conclusion drawn that the lack of proper planning leads to a cluttered and incoherent building site (Valen & Larssen, 2006). Although projections can be reasonably accurate for about 3-5 years into the future (Westlake Jr, 1995), some hospitals have been carefully designed to consider the entire lifecycle. The Martini Teaching Hospital in Groningen, Netherlands, showcases some of the most innovative approaches in masterplanning and building design. For its masterplan, the 'empty chair' approach is applied, based on the 'four quadrant' principle. One 'quadrant' of the building site is left free from construction so that as the buildings age and repairs, extensions or renovations are needed, construction can take place in the dedicated area, thus eliminating disruptions to patients (Thiadens, et al., 2009).

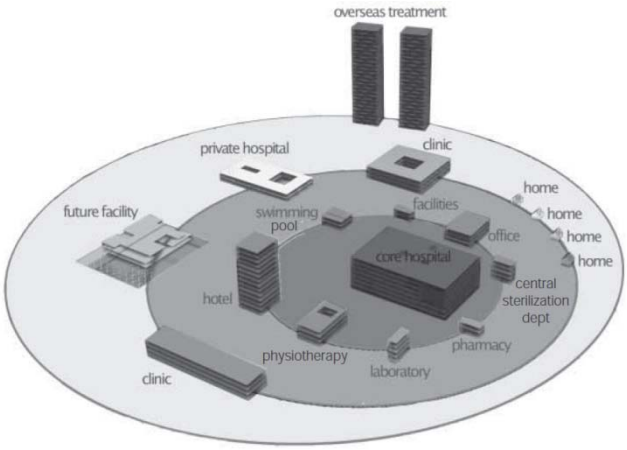


Source: Architect Burger-Grunstra, as reproduced in (Thiadens, et al., 2009)
Figure 7 - Future Planning Stages of the Martini Hospital, Groningen showing the 'Four Quadrant' approach

Three main considerations at the masterplanning stage include (Westlake Jr, 1995):

1. The new hospital's proximity to other hospitals
2. The catchment it services
3. Future expansion opportunities.

One should also consider whether it is better to design a comprehensive hospital building if the availability of space means that it will be on the outskirts of town, or build a series of smaller hospital facilities in the inner city area, where public access is more readily available. The latter is dubbed the 'Core Hospital' by Venhoeven/Guthknecht architects, whose studies found that as little as 50% of the traditional floor area was needed and the rest can be cast off in ancillary buildings around the Core Hospital (Bjørberg & Verweij, 2009). Worthington (2008) and Diamond (2006) go one step further to suggest that to provide maximum flexibility responding to patient and space demands, and in consideration of the rising trend in home delivered care, the hospital of the future may consist of a main hospital with other surrounding buildings on an as-need or on-demand basis. Taking cues from the commercial sectors, these complimentary facilities may be owned by others or rented out for external uses, with the option to turn them into a hospital when the need arises. These added flexibilities can be incorporated into the contract by the use of option fees (Lee, 2007).



Source: Netherlands Board for Healthcare Institutions, as reproduced in (Bjørberg & Verweij, 2009)
Figure 8 - The Core Hospital - Netherlands Board for HealthCare Institutions

5.3 Building design and construction

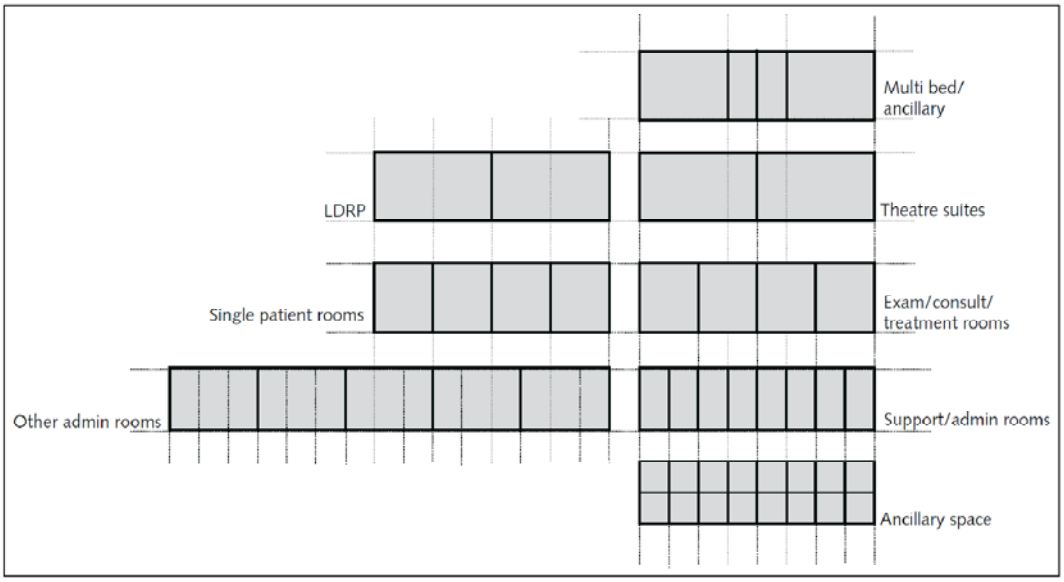
When considering flexibility and adaptability during the design stage of healthcare facilities, the following properties should be considered (Valen & Larssen, 2006):

- Standardisation and modular architectural layouts, leading to less variation of room sizes
- Zoning and layering of operational functions
- Dimensions of structural elements such as the core space, floor plate dimension, and interstitial floors
- Calculated capacity of HVAC, wiring, ICT and other electrical and communication network
- Construction for future vertical and horizontal expansion.

There is a wealth of research in the area of hospital design (see Kliment, 2000 for information on hospital layouts and design), with recommendations for appropriate grid size, room layouts and the like. This information is insightful but of course is also required to be tailored to different situations.

Modular architecture

Whilst some designers, notably Neild (2008b), believe that modular planning will soon be overtaken by the 'hanger building' modelled on airport buildings which leaves the floor plans free from structure and thus more easily adapted to other purposes, it appears that the majority of designers are exploring ways to refine the modular approach. The idea behind modular architecture is to be both 'fit for purpose' at any given time, whilst incorporating options that can service a range of plan depths to suit different activities and service conditions. This concept relies on a uniform grid and a system of core distribution which can then be reconfigured or subdivided in the future (Diamond, 2006).



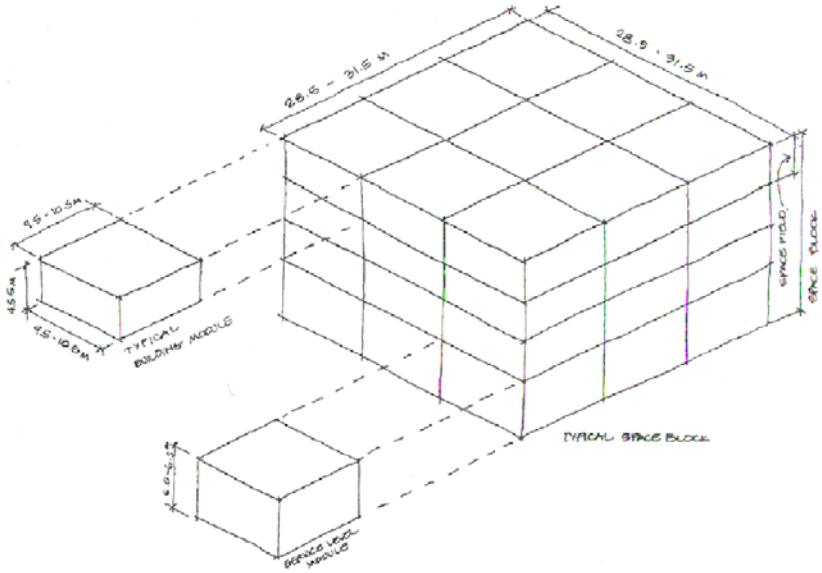
Source: (Diamond, 2006), p. 35

Figure 9 - Grids for Planning Common Hospital Rooms and Spaces

The grid size ranges but seems to fall between around six to nine square metres. Diamond identified some common grid sizes for hospitals, which are listed below from *most* to *less* flexible:

- 8.1 m grid (1.35 m x 4.05 m)
- 7.2 m grid (1.8 m x 3.6 m)
- 7.5 m grid (1.875 m x 3.75 m).

Jonassen, et al. (2001) explored options in terms of volumetric spaces rather than two dimensional grids, and identified 'space fields' and 'universal building blocks' as modules that could serve varying hospital functions. For example, a three module cube of roughly 30m x 30m works well for diagnostic and treatment functions, inpatient and outpatient functions and service functions. This also works relatively well as the structural grid for the car parks underneath the building. Jonassen recommends a 10m x 10m square block module, but notes that these dimensions may vary slightly depending on local legislative codes and planning guidelines.



Source: (Jonassen, et al., 2001), p. 262
Figure 10 - Flexible Building Modules

Acuity-adaptable and universal rooms

Whilst it is easy to conclude that the standardisation of rooms in general will lead to greater flexibility in planning and operation, in reality the acuity-adaptable room was created mainly due to concerns for patient-safety as a result of transfers between and within facilities, and to address operational issues such as the uneven flow of patients in need of high acuity care that causes bottlenecks in the use of wards and other healthcare spaces (Reiling, et al., 2004). Each acuity-adaptable room should be equipped with the full range of equipment and medication that could cater for the majority of treatments and procedures required. This removes the need for moving the patient around different parts of the hospital for treatment or procedures and standardizing the layout of each room lowers the risk of associated patient falls, patient hospital acquired infections and clinical errors. The acuity-adaptable room is based on a 'process based organisational approach'

which allows the patient to be the primary focus of the care process. The patient is then treated in one room with the supporting functions provided to that room. This is the opposite to a 'function based organisational approach' which has centrally-managed functional departments which the patient has to be moved around in order to be treated (Diamond, 2006). Acuity-adaptable rooms should be a minimum of 23m^2 to 25m^2 (Gallant & Lanning, 2001), whereas basic standardised rooms can be much smaller, such as the ones in St Olavs Hospital, Oslo, which are 14-16m^2 for patient rooms and 16m^2 for examination rooms (Valen & Larssen, 2006).

The acuity-adaptable room system has received mainly positive feedback, including clinical data regarding reduction in patient falls at the Cardiac Comprehensive Critical Care department at Clarian Health, Indianapolis in the USA (see Section 4.4 and Hendrich, et al., 2004). Despite the proven benefits, one criticism identified by Clarian Health's president and CEO is that the system "assumes a nurse is a nurse is a nurse", without differentiating high-acuity nurses with low-acuity nurses (Scalise, et al., 2004). The reality is that nurses will travel through greater distances in the hospital building in order to deliver care to the patients in this scenario.

Room layout and zoning of functional requirements

In order to plan for convertibility in the future, the various functions in the healthcare building should be arranged so that functions and facilities with similar life spans are grouped across the floor plans for different buildings and levels of buildings. For example, St Olavs Hospital in Trondheim, Norway was designed so that functions in one centre could be easily expanded into another centre while the continuous surgery and critical care area ('hot floor') remained on the 1st floor and the university area continued to occupy the 2nd floor (Jensø & Haugen, 2005).

The facilities to be designed can be evaluated in terms of their expected service life period (SLP). The shorter a function's service life period, the more frequently the facility that supports that function will need to be upgraded to keep up with operational and technological demand. Hence the requirement becomes that the space must be more flexibly designed (Bjørberg & Verweij, 2009). On a more micro level of hospital floor design, pockets of 'shell' or unassigned space ('soft space') should be designed near areas that are predicted to have high growth, such as putting examination or diagnostic areas adjacent to patient waiting rooms. The permanent 'core' programs in general should be provided with a decent buffer as they will be difficult to relocate later on. Furthermore, corridors should be open-ended where there is the potential to expand the building in that direction (Westlake Jr, 1995). These soft spaces include nurse stations, nourishment stations and medication stations, which are easy to prefabricate and design as a module; other spaces with fire rating requirements such as lounge/locker rooms, clean and soiled utility rooms and larger storage areas which can also easily be placed behind prefabricated walls (Datta, 2000). As a rule of thumb, circulation space should be between 30-35%, and even up to 40% in some instances (Potter, 2008).

Building design

Nitch (2006) and others suggest that decentralisation and the employment of smaller hospital footprints are the key to providing the flexibility and efficiency required. In his example, a 'vertically stratified' building is designed such that each floor contains a diagnostic and technology zone, an

inpatient or nursing zone and public and administrative zone, with the vertical circulation and service amenities embedded within a central utility that serves all components of every floor. At the Cardiac Comprehensive Critical Care department at Clarian Health, Indianapolis in the USA, where a decentralised design was utilised, at first nurses reported they felt 'isolated' and a higher nursing staff turnover was witnessed. However after the first year of operation, new nurses report they like the 'continuum of care' and the staff turnover rate has reverted back to normal (Scalise, et al., 2004).

The 50,000m^2 INO building at Insel Hospital in Bern, Switzerland, utilized an 'Open Building' strategy where the building structure was split into Primary (building shell - 50-100 years), Secondary (walls and ceilings - 15-50 years) and Tertiary (Furniture and fitout - 5-10 years) systems. Because of the constant changes that need to occur in large and complex buildings, a hospital of this scale is never fully 'complete'. In recognition of this fact, discrete systems are employed whereby the Primary, Secondary and Tertiary systems are treated with autonomy, to the extent that they are designed by different architects and built under discrete contracts (Kendall, 2005a).

During the construction phase numerous problems arose for the INO Building, mainly due to time overruns caused by the delay of schedule. Geiser (2004) attributes this to the complexity of the project, rather than the idea of discrete systems. However, he also notes that the interface between the contractors for the primary and secondary systems, the overall larger number or participants involved and the difficulty of exercising changes which impacted upon another party or a previous system are the main problems of using discrete systems. Anecdotal report is that the building also did not turn out as originally envisioned. This was said to be due to the insistence to pack as much function as possible into a given space and the amount of detail in the planning of clinical facilities compromised the original simplicity in design concept (M. Smith, personal communication, October 27, 2009).

Construction components and methods

Barlow & Koberle-Gaiser (2009a) noted that architects and those developing the building contract must not over-specify construction methods. This is supported by studies of French hospital designs, which showed that their contractor-led approach has been beneficial as contractors will utilise simple construction methods which save on costs (Building Design Partnership, 2004).

As can be imagined, due to the rapid rate of technical advancements it is difficult to design for flexibility based on future predictions. A surplus capacity of 20-30% on HVAC, wiring and ICT was designed into St Olavs Hospital in Trondheim (Valen & Larssen, 2006). As for MEP (Mechanical, Electrical and Plumbing) systems, flexibility measures include using identical or multiple parts so that the building can be easily modified or isolated for renovations and expansions (Gupta & Marshall, 2005).

5.4 Operational

As noted by Johnson (2004), hospital administrators are really also real estate managers. Flexible operational approaches may lead to greater operational efficiencies but also require a greater

necessity for flexibility in spatial organisation. Whilst standardisation of operational processes is important, there are also limiting factors to this approach. In terms of operational efficiencies that may be achieved, Rechel, et al. (2009) suggests that an 80:20 rule is followed - by identifying the nature of processes, 80% of the activities might be able to be standardised leading to cost savings, and the other 20% will be subject to fluctuations in demand or other issues requiring a change in practices and/or spatial provision.

For example, at the New Northwestern Memorial Hospital, Chicago, admission basically takes place at the bedside (or within outpatient departments), eliminating the associated administration function, and the need for separate spaces to support it. This is done by notifying patients the night before a scheduled admission and directing them to go straight to their preassigned room (Briggs & Barnard, 2000).

5.5 Conversion, Renovation and Decommissioning

A hospital building may undergo one or more renovations in order to achieve a structural life in excess of 50 years. However, whilst its internal functions flux as needed, it may also have components decommissioned along the way. As the building ages, areas that can no longer cope with new advances or functional requirements may be converted to a less technologically demanding use (Bjørberg & Verweij, 2009) - for example conversions of operating theatre spaces to inpatient accommodation use, or converting outpatient spaces to administration offices or meeting rooms.

When a hospital building finally reaches the end of its useful lifecycle, it may often be more appropriate for the whole facility to be converted to another use such as commercial office space or an apartment building. However this will only be feasible if the initial design of the building allows for this change to occur. To take into consideration the eventual decommissioning of the hospital building at the Martini Teaching Hospital in Groningen, Netherlands, the design veered away from deep floor plans to a 16m x 60m plan, the configuration of which could easily be adapted for use as office or apartment blocks (Thiadens, et al., 2009). Coincidentally this building configuration, already used in French hospitals (Building Design Partnership, 2004), allows for increased sunlight into the building which is shown to be beneficial for patient wellbeing (Cama, 2009). The recognition of these potential uses allows the Martini Teaching Hospital to be valued independent of its medical functions, beyond a hospital building.

6.0 Discussion

6.1 Application in the Australian context

Although this research was primarily focused on international research and case studies, it has also touched on Australian experience and projects. Requirements for hospital design and function are quite similar across the western (developed) world, although clearly some aspects are also influenced by local codes, guidelines and legal requirements. Apart from differences associated with the building structure, construction methods and module sizes as advised by Jonassen, et al. (2001), local building codes also have direct implications for building planning and design. An example is the requirement in France that all rooms where people work have access to daylight - "At least 25% of the window wall be glazed and that the view should be onto a courtyard of a minimum of 7m width or wider if the court is taller than two levels" (Building Design Partnership, 2004, p. 16). Similarly in Australia, the Building Code of Australia impacts on such issues. Differing funding methods also result in different emphases on operational and design requirements. Whilst this report elaborated on the UK's PFI system which is seen to have more relevance to the Australian interest in PPP/PFI, it also drew case studies and research from other countries such as the USA which have different funding structures and attitudes to provision of universal healthcare. It is therefore particularly important that the findings in Section 5.0 of the report not be taken at face value but be tested for the Australian context first. This could be done by using simulation software to evaluate current or planned projects, or by conducting further research in various case studies available across Australia. This is noted in the following section drawing conclusions from this study.

Datta (2000) points out that when trying to design or implement flexible design, the biggest obstacle may relate to compliance with local building codes which by defining the framework for design can result in a facility being unable to cope with future technological advances. Flexible design should therefore be incorporated as a 'guiding principle' in the broader umbrella of healthcare development strategies that can then be refined and carried throughout local planning documents and PFI contracts. As discussed in Section 4.4, flexibility should not be considered as a standalone object; any design policy addressing flexible design should include this as part of a holistic approach to the design of future hospitals. Such an approach may also encompass other priority issues such as patient focused care, provision of humanistic environments and a commitment to environmentally sustainable design. Policy makers should refer to existing policies from overseas such as the *Health Care at the Crossroads: Guiding Principles for the Development of the Hospital of the Future* report prepared by the US based Joint Commission (The Joint Commission, 2008).

6.2 How to measure flexibility performance?

The performance of a hospital can be measured both quantitatively and qualitatively. Measureable outcomes include factors such as operational costs and annual financial output, assessed quality of patient care, staff turnover rates, and patient safety issues such as rates of hospital acquired infections and the number of patient falls. Some of the impacts of design decisions can be measured

using evidence-based design methods, which isolate design elements and systematically compare how that design element affects medical outcomes (Cama, 2009). A simulation system could also be used to test the flow, adaptability and usability of spaces. Vos et al. (2007) uses 'discrete event simulation' and uses 'degree of circulation and flow', as opposed to congestion, to measure the suitability of a space when subject to different levels of patient flows. A full mock-up of parts of the hospital, such as an acuity-adaptable room, could also be used to explore ideas and test likely operational flexibility (Scalise, et al., 2004). Such a mock-up could be done either physically or using virtual modelling techniques.

Construction cost and overall user satisfaction ratings may also be used to measure hospital performance (Building Design Partnership, 2004). The overall flexibility performance of a hospital is best measured by identifying flexible elements from different hospitals and comparing like with like. This method was used with success in Valen & Larssen's (2006) comparison of six Norwegian hospitals, where they identified key performance criteria such as floor loading capacity, loading of internal wall and HVAC surplus capacity. The data are then correlated with how well the case studies managed to cope with change - however, it should be noted that this part of the study, including the conclusions, was mostly based on anecdotal evidence or expert opinion rather than on quantifiable research evidence.

New hospital developments should use the lifecycle approach advocated by Bjørberg & Verweij (2009) and itemized business case comparisons such as Sadler, et al. (2006) for their initial financial analysis and update this annually during its operation to monitor whether or not a) the flexibility measures designed for were utilized; and b) whether these achieved the cost savings intended. This could be incorporated as part of the hospital's post occupancy evaluation program and the success and failings measured should be recorded and analysed.

6.3 Limitations of study

The search frame for the study was limited to articles dating 1989 to 2009, and focused primarily on recent case studies built in the past 10 years that demonstrate innovative and flexible design. Many of these case studies are only newly completed and some of them, for example the St Olavs Hospital, are not yet complete. It is hence impossible to foresee how these hospitals will perform in the next few decades. As NSW Health plans on designing hospitals to last at least for the next 30 years, looking further into the past than the last 10-20 years may be worthy of greater consideration. This could allow an understanding of historical trends and approaches to flexible and adaptable design, especially those resulting from projects completed during the 1960's and 70's when design flexibility appears to have been explored more extensively. As the concept itself is timeless and has been much explored over the last century in many countries, much may be learnt from studying case studies based on older hospitals in order to see how these have coped with change over their life spans. It is therefore suggested that any further research should wider the search frame to include earlier articles and research on the subject.

Additionally, due to the time constraints, the literature search was limited to items that were readily obtained. However, notwithstanding this, a sufficient number of sources were reviewed to allow a

comprehensive overview of the research being done on the topic. But it should be noted that some of the sources uncovered in the initial search were not available via the UNSW library network or Inter Library Loans and could be further pursued via other sources. Similarly, some of the overseas professionals and researchers contacted did not respond in a timely enough manner to enable their insights to be incorporated into this report. These experts could be further consulted in the future.

7.0 Conclusion

7.1 Summary

This report was commissioned in response to Health Infrastructure NSW's recognition of the need to design flexibility and adaptability into NSW hospital infrastructure to accommodate the varying operational needs of the foreseeable future plus the necessity to consider responses to future change requirements over the whole potential lifespan of a facility. The research was conducted based on a systematic review process. It looked at flexibility and adaptability in hospital infrastructure as manifested in design approaches in the international context, while focusing particularly on practical applications and case studies.

Although there is a wealth of information on designing for flexibility in the hospital environment, the material is often selective and fragmented, which works against developing a more comprehensive overview of current literature on the topic. Moreover, it is found that the idea of flexibility has many facets, often quite ill-defined or used purely rhetorically, and thus the concept needs to be broken down for further analysis and consideration.

The report first redefined the common terminology used by looking at flexibility at the macro and micro scales, and how it may be considered throughout the various stages of the project lifecycle. The conclusions drawn include the contention that flexibility should be considered as a system that is applicable at many levels of project design and implementation, rather than as a standalone concept that can be used as a cover or 'motherhood' statement. Further, strategic, managerial, operational and other policy issues impact on the flexible performance of the physical facility at least as much as its initial design. These issues need to be considered in terms of their positive or negative influence on the project desired outcomes and addressed accordingly.

7.2 Recommended future research

Whilst the research found references to several local (NSW) case studies including St Vincent's Hospital (Farrelly, 2002), Westmead Hospital, Prince Alfred Hospital, Coffs Harbour Hospital and Prince of Wales Hospital (Neild, 2008a), the study of Australian hospital design, and in particular the approach to flexibility and adaptability in the design of local facilities, appears to be an opportunity not yet realised. For Health Infrastructure NSW, the first recommendation of this report for future research is that existing Australian healthcare assets should be evaluated in terms of their past ability to flex and change, which could yield important insights into future directions for healthcare design. The hospitals listed by Neild above could provide a starting point for such a study noting that NSW hospitals provide many of the examples given.

Secondly, also needed is greater sophistication in the methods used for measuring the effects of designing hospitals for flexibility beyond the usual exploration of initial capital cost and the more occasional considerations of patient safety and staff turnover implications relating to facility design. There are few projects really (and seriously) designed for flexibility, although many hospitals claim to

be 'flexible'. Often, further analysis of such claims reveals the fact that the descriptions given are vague or rhetorical, and the research has been done with little rigor. Indeed, anecdotal evidence suggests that on many projects, design for expansion, contraction, future alteration or other uses, is not infrequently 'value managed' out at an early project stage in order to meet present day capital budget limitations. It may be worthwhile to adopt a longer term, scenario focused approach to project lifecycle costing (informed by the type of research proposed by this study) in order to truly understand the implications of such 'value management' decisions for the future of NSW healthcare buildings, the next generation of healthcare consumers - and indeed for the NSW community as a whole.

Finally, a standardised set of terminology that more clearly defines concepts of 'flexibility' and 'adaptability' for healthcare facilities is urgently needed. This would assist in developing a more systematic approach to the analysis of new and existing healthcare infrastructure in terms of these concepts. Development of this approach could be based on some of the theories of analysis that have already been researched internationally and discussed in the earlier sections of this report. It would also ensure that those investigating or researching the subject can compare results and create a more encompassing body of knowledge than that which currently exists.

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Appendix 1 - List of Major Case Studies

Healthcare asset	Description	Location	Completed	Source
Addenbrooke's Hospital	The old hospital (1,100 beds) was relocated to cope with expanding functions.	Cambridge, UK	Final transition to a new hospital completed 1984	(Neufville, et al., 2008)
Banner Estrella Medical Center	This hospital was designed to facilitate future expansion.	Phoenix, USA	2005	(Eagle, 2006)
Celebration Health	Universal room design leads to reduction in average lengths of stay and nursing hours per patient day.	Orlando, USA	Unspecified	(Gallant & Lanning, 2001)
Clarian West Medical Center	Clarian West was constructed with universal patient rooms. The size of the room and the configuration can serve all the purposes from medical-surgical to labour and delivery to intensive care.	Avon, Indianapolis, USA	2004	(Eagle, 2007)
Clinica Las Condes Medical Centre (CLC)	CLC is now planning for a major expansion, adopting flexibility mainly through standardised spaces, same-handed rooms, pod design, and shell spaces.	Santiago, Chile	1982 (renovation 2000s)	(Pressler, 2006)
Insel Hospital	First medical facility in the world where 'open building' management principles were applied to the design of a large medical complex.	Bern, Switzerland	2009 (second stage)	(Geiser, 2004; Kendall, 2005b)
John H. Stroger Jr. Hospital	Very large facility (3 football fields long); pattern repeats itself on first 5 floors; modular design - modules connect at the intersection of a horizontal/vertical core; outpatient clinical clustering.	Chicago, USA	2002	(Doiel & Loharikar, 2003)
Loma Linda University Hospital	Retrofitted single-stay unit leads to reduction in average length of stay.	California, USA	Unspecified	(Gallant & Lanning, 2001)
Martini Teaching Hospital	Incorporating a teaching hospital, operating specialist services and general hospital.	Groningen, Netherlands	2007	(Thiadens, et al., 2009)

Healthcare asset	Description	Location	Completed	Source
McMaster Health Sciences Centre	The building was designed for maximum flexibility, including vertical and horizontal expansion. These measures were in the end unfortunately not utilized.	Ontario, Canada	1972, latest refurbish-ment in 2002	(The American Institute of Architects, 2005; Verderber & Fine, 2000)
MedCath	Nation-wide chain of 40-60 bed speciality heart hospitals. Universal room design.	Various, USA	Unspecified	(Gallant & Lanning, 2001)
Methodist Hospital, Arcadia	The nursing control station plan for Methodist Hospital, Arcadia, California, U.S.A. is an example of a flexible staffing model floor-plan.	Arcadia, California, U.S.A		(Pressler, 2006)
Methodist Hospital, Indianapolis	Contains an acuity adaptable 56-bed cardiac critical care unit.	Indianapolis, Indiana, USA	Unit opened 1999	(Gallant & Lanning, 2001; Hendrich, et al., 2004; Sadler, et al., 2006)
Northwestern Memorial Hospital	Replacement hospital with new medical office building. Facility designed reflecting adaptable building infrastructure, modular planning and functional adaptability, patient safety and sustainability.	Chicago, USA	May 1999	(Briggs & Barnard, 2000; Olson, 2008)
Royal Victoria Infirmary	Eye clinic; illustrates the successful integration of flexible design for PFI hospital project.	Newcastle-upon-Tyne, UK	1996	(Lee, 2007)
St Joseph's Community Hospital	Independent, non-profit approx. 80-bed acute care facility; safety driven design process.	West Bend, Wisconsin, USA	2005	(Reiling, et al., 2004)
St Olav's Hospital & Trondheim University Hospital	University hospital focused on patient-centred care and integrating teaching and research.	Trondheim, Norway	2014	(Jensø & Haugen, 2005; Rechel, et al., 2009; Valen & Larssen, 2006)
St Vincent's Hospital	Redevelopment under the idea of 'growth-and-change'.	Darlinghurst, NSW, Australia	Late in the 1990s	(Farrelly, 2002)
The Ohio State University Richard M. Ross Heart Hospital	A specialty hospital dedicated to the treatment of patients with cardiovascular (CV) disease and incorporating an academic medical centre.	Columbus, Ohio, USA	2004	(Bush, et al., 2005)

Appendix 2 - Operators and Truncation Symbols

Although electronic database searching seems simple, it is, in practice, difficult to efficiently acquire relevant studies under time and cost constraints (Counsell, 1997). It requires the involvement of professionals such as librarians who are experienced with the particular database. While appropriate combination of key words is the key factor, expertise is necessary for the correct use of connectors, operators, and truncation symbols, as each database might adopt different rules in applying them. The connectors, operators and truncation symbols used for our research are listed below:

Databases	***Connectors, operators, and truncation symbols***
ARCH	* = truncation (zero, one or more characters) Boolean: AND,OR Phrase searching: automatic
Avery	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching: automatic
MEDLINE	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching: automatic (quotation marks have been used when 'and' is in a phrase)
ICONDA	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching: automatic (quotation marks have been used when 'and' is in a phrase)
BUILD	* = unlimited truncation Boolean: AND, OR Phrase searching: automatic
Compendex	* = truncation (zero, one or more characters) Using truncation OR wildcards will turn off the stemming feature. Boolean: AND, OR Phrase searching = "quotation marks"
ENGINE	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching: automatic (quotation marks have been used when 'and' is in a phrase)
Scopus	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching (approximate or loose) = "quotation marks"
RIBA	* = truncation (zero, one or more characters) Boolean: AND, OR

Databases	***Connectors, operators, and truncation symbols***
Web of Science	* = truncation (zero, one or more characters) $ = zero OR one character Boolean: AND, OR Proximity search = SAME (find records where the terms separated by the operator appear in the same sentence) Phrase searching = "quotation marks"
AMI	* = truncation (zero, one or more characters) Boolean: AND, OR Proximity searching: NEAR (Finds records that contain terms in the same sentence) Phrase searching = automatic
Business Source Premier	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching = automatic (quotation marks have been used when 'and' is in a phrase)
Academic Research Library	* = truncation (zero, one or more characters) Boolean: AND, OR Proximity searching: W/# (words are within some number of words apart, either before or after) Phrase searching = automatic
APAIS	* = truncation (zero, one or more characters) Boolean: AND, OR Phrase searching: automatic (quotation marks have been used when 'and' is in a phrase)
ABI/Inform global	* = truncation (zero, one or more characters) Boolean: AND, OR Proximity searching: W/# (words are within some number of words apart, either before or after) Phrase searching = "quotation marks"
Google Scholar	45 combinations of the following keywords: Hospital, healthcare facility, health infrastructure, health facility, medical facility Architecture, design, construction Flexible, flexibility, future, adaptable, adaptability
Google	15 combinations of the following keywords: Hospital, Healthcare facility, Health infrastructure, Health facility, Medical facility Design, architecture, construction Flexible, flexibility, future, adaptable, adaptability

Appendix 3 - Literature Review Matrix

Reference	Nationality	Main findings	Process & issues	Facility					Stage					Context						Method					
				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Barlow & Koberle-Gaiser, 2009a)	UK	The research found that the government's goals of transferring risk onto the SPV led to a bidding process that focused on the distribution of risk to the detriment of potentially innovative design.	The research was taken in three stages - conducting interviews with field experts, short case studies of historical hospitals (built 1970-80's) and detailed studies of seven PFI schemes.	√				√		√	√							√					√	√	
(Barlow, et al., (2009b)	UK	Research found the PFI process stifles innovation due to poor project communication, risk aversion and the overly tight control of capital spending. It also found there is a lack of serious data and analysis relating to adaptability and flexibility in NHS hospitals.	Research is undertaken by The Howard Goodman Fellowship to explore the relationship between the PFI delivery mechanism for healthcare infrastructure and the potential to accommodate future changing needs, especially through flexibility and adaptability in the built form.	√				√		√				√			√	√					√		

Nationality	reference's country of origin	**Context**	why is flexibility and adaptability stated as necessary
Facility	the type of healthcare asset discussed	**Method**	research method employed
Parameter	what they are discussing in the article	**Case study**	case stud(ies) discussed (ref. Case studies list document)

Reference	Nationality	Main findings	Process & issues	Facility				Stage						Context						Method					
				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Bjorberg & Verweij, 2009)	Netherlands	When creating a financial analysis, a lifecycle approach needs to be applied. Functions are categorised according to their "service life periods" (SLP) - which denotes the period between each refurbishment. Adaptability is particularly important for functions with a short SLP.	In the healthcare industry there is a lack of awareness as to the cost and benefit of capital investment. These become apparent when considering the lifecycle of a project rather than just the initial capital costs. By considering the lifecycle principles, additional costs incurred by applying flexibility measures can be justified through savings in the building's future.	√				√	√								√						√		
(Briggs & Barnard, 2000)	USA	The New Northwestern Memorial Hospital in Chicago, USA was opened in May 1999. Some patient centered strategies are highlighted, including specific flexibility measures for the radiology and diagnostic imaging areas and operation rooms, with seemingly good results.	Since the article is published less than a year after the completion of the hospital and the authors are employees of the hospital, the objectivity and applicability of these measures will need to be verified.	√						√	√	√				√							√		√

Nationality reference's country of origin
Facility the type of healthcare asset discussed
Parameter what they are discussing in the article
Context why is flexibility and adaptability stated as necessary
Method research method employed
Case study case stud(ies) discussed (ref. Case studies list document)

Reference	Nationality	Main findings	Process & issues	Facility						Stage						Context						Method					
				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Building Design Partnership, 2004)	UK	Contractors are in charge of the detailed design and construction stage, which leads to a focus on simple, low cost construction technology and methods. French policy for daylight access with outlook to a courtyard space also has positive design implications for French hospitals.	This report, compiled by Building Design Partnership (BDP) and drawing upon the expertise of BDP's associate practice Groupe-6, compares seven UK and seven French hospitals, looking at their procurement strategies and design objectives and methods in particular.	√				√	√	√	√	√		√			√	√					√		
(Bush, et al., 2005)	USA	The hospital advocates the Universal Room concept because it eliminates the need for specialised care units by allowing the patient room to adapt to the level of acuity.	This detailed case study of the Richard M. Ross Heart Hospital records the project from pre-design conception through project financing to its construction and opening. However, the article lacks floor plans or design details from whence design principles could be extrapolated.	√				√		√	√			√			√						√		

Nationality reference's country of origin
Facility the type of healthcare asset discussed
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Reference	Nationality	Main findings	Process & issues	Facility						Stage					Context					Method					
				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Cama, 2009)	USA	The idea of evidence-based medicine can be applied to design by the implementation of a decision-making process that begins with the analysis of current best evidence and linking design objectives to outcomes.	This book outlines the process of planning and designing a project using evidence-based design principles whilst providing tools for doing so. It offers ideas that can then be adapted for individual cases without being prescriptive.	√						√				√					√			√	√		
(Datta, 2000)	USA	Hospitals need to be designed and constructed using a “Universal” nursing unit to enhance the flexibility of the infrastructure; but also to maximise the contact between the patient and physician.	The paper began with historical analysis of hospital development, highlighting how new technology led to design changes. It draws on case studies and identifies specific areas where flexible elements may be employed.	√						√				√			√						√		

Nationality reference's country of origin
Facility the type of healthcare asset discussed
Parameter what they are discussing in the article
Context why is flexibility and adaptability stated as necessary
Method research method employed
Case study case stud(ies) discussed (ref. Case studies list document)

Reference	Nationality	Main findings	Process & issues	Facility						Stage					Context					Method					
				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Diamond, 2006)	UK, USA, Spain, Norway, Germany, Denmark, Netherlands	By studying emerging healthcare trends, plus learning from other sectors as well as existing operating hospitals, key design principles are extracted to propose future-proof solutions for new and planned hospitals.	Various drivers for change are explored, with particular emphasis on how IT has altered the way people work. The research logically derives its conclusions by first analyzing at the macro scale before studying various case studies in more detail.	√				√		√	√	√		√	√		√						√		
(Doiel & Loharikar, 2003)	USA	The design for the new John H. Stroger Jr. Hospital, Chicago, includes flexibility-related features such as standardised modular design and clustering of outpatient clinics with similar functions/clientele.	Brief case study. Useful for introducing a case study but not much detail is given, apart from the two methods proposed for achieving flexibility. Shows that flexibility was a main concern for this hospital design.	√						√													√		

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(Eagle, 2006)	USA	Banner Estrella Medical Center, Phoenix, uses site master planning, a central spine, built in capacity for electrical/IT/sewer systems, acuity adaptable rooms and standardised room/floor designs to provide for future flexibility.	Brief case study with main focus on flexibility. Much practical information is given regarding how flexibility is being designed into new construction; the benefits, including cost effectiveness, are also briefly discussed.	√					√	√	√				√	√	√						√		
(Eagle, 2007)	USA	Case study of Clarian West Medical Center, Indianapolis which was built for flexibility by using large universal patient rooms, acuity adaptable rooms, shell space and a masterplan. Two years after the facility was built the intensive care unit was able to be re-positioned with no associated construction costs.	Brief case study, but provides a real-life example of design elements for flexibility, and of change able to be easily implemented because of the inbuilt flexibility features.	√					√	√	√			√			√						√		

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(Farrelly, 2002)	Australia	St Vincent's Healthcare Campus in Darlinghurst was redeveloped under the idea of 'growth and change.'	Although it is a general description about a process and features of a redeveloped hospital, it contains some relevant information about design for the future.			√				√				√									√		
(Gallant & Lanning, 2001)	USA	Explanation of flex unit, universal, acuity-adaptable and single stay unit room designs. Benefits include less transfer time, continuity of care and nurse retention. Design features of flexible patient rooms are examined including size and layout. Includes four case studies.	In depth article, includes history, theory and benefits of flexible room design. Plans and case studies included with data to prove benefits. Practical design elements can be extrapolated. The authors are from Hill-Rom company (a manufacturer of medical technologies) so objectivity of this article would need to be verified.	√			√			√				√		√							√	√	

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(Geiser, 2004)	Switzerland	Renovation has been undertaken on the west wing of the Insel Hospital in Bern, Switzerland. A separate (discrete) planning method has been applied.	This conference paper presents an exemplary case for a flexible and adaptable planning. However, it does not show the detailed outcomes of the discrete planning method.	√						√	√	√											√		
(Gupta & Marshall, 2005)	USA	Greater emphasis is being increasingly placed on the mechanical and electrical infrastructure of hospitals and the need to adjust to new technologies. Thus, the use of technology should be considered at the design stage.	This paper present three hospitals that incorporate technology needs in flexible and adaptable ways.	√						√		√		√	√								√		
(Harvey & Pati, 2008)	USA	Magazine style summary of previous scholarly article: (Pati et al, 2008). A survey identifies 9 attributes of health facility design flexibility - mostly operational and adaptability of spaces.	Magazine style writing is useful to interpret the scholarly article. Easy to read summaries and dot-pointed design solutions under 'What Works' headings for each attribute.	√						√		√		√								√		√	

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(Health Care at the Crossroads, 2008)	USA	The report identifies flexibility as one of the principles to guide design and provides description on the topics: master planning strategies, loose-fit design, adaptable flexibility, convertible flexibility, robust utilities and plug-and-play infrastructure.	Borne out of panel of experts evaluating current hospitals and giving guidelines for the future, the report provides a short overview to understanding the challenges of hospital design today, but does not provide details that can enable better design.	√			√		√	√				√	√	√			√					√	
(Hendrich, et al., 2004)	USA	Acuity-adaptable rooms allow care for more patient days in fewer beds. Transports of patients decreased by 90% and medication errors decreased by 70%.	The paper uses the Methodist Hospital, Indianapolis, as a case study, where a new Cardiac Comprehensive Critical Care unit contains 56 acuity-adaptable rooms and was opened in 1999.	√						√		√		√		√							√		
(Jensø & Haugen, 2005)	Norway	St. Olav's hospital in Trondheim, Norway, is a new hospital, rebuilt under the principles of 'patient in focus.'	The main focus of this conference paper is patient focus design and its usability. Design for flexibility is limitedly dealt within patient focus design solutions.	√						√						√							√		

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(Johnson, 2004)	USA	Key areas of flexible design include nursing units, emergency department, surgery, imaging, and ambulatory services.	No concrete case study or design feature is presented in this paper. However, it identifies hot spots that must be considered in flexible design.				√			√				√										√	
(Jonassen, et al., 2001)	USA	A flexibility strategy for health facility design is developed, addressing pragmatic requirements of a hospital such as people movement and mechanical distribution, giving diagrammatic examples for possible modules and systems for each.	The main strength of the article is in its ability to produce universal design principles articulated as workable grids and layouts that can then be applied to a specific local context.	√					√	√														√	
(Kendall, 2005b)	Switzerland	A new method for procuring hospital facilities was used for the construction of the Insel Hospital in Bern, Switzerland. 'Distributed design management' was a key concept.	This conference paper reviews Insel Hospital, Bern, Switzerland. However, it presents more detailed methods and design features.	√						√	√	√											√		

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(Kliment, 2000)	USA	Although flexibility is not a main focus of the book it is embedded in the overall design considerations. The cross references make it easy to see where flexible design might be applicable, and the numerous examples and data show how it might be done.	This book is intended as a one stop, quick reference guide for architects, consultants and their clients when starting up a project. The cross references make it easy to see where flexible design might be applicable, and the numerous examples and data show how it might be done.	√	√	√				√				√	√					√			√		
(Kumar, 2000)	India	This article identifies some key design parameters such as the evaluation of space allocation for “super-speciality hospital” and “multi-speciality referral”.	Although highlighting some of the main concerns for flexibility the article falls short on giving specific, practical advice on possible implementation of flexible designs.	√						√				√			√							√	√
(Lam, 2007a)	Hong Kong	Sufficient allocation of site is a prerequisite for future development and additional 50-60% of the foundation area is recommended for any possible expansion.	This conference paper presents some key principles for flexible design. However, no specific case is mentioned. Thus, it is close to theoretical and weak in providing practical implications.				√		√	√					√				√					√	

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(Lam, 2007b)	Hong Kong	Maintenance should be considered as an integral part of flexible design and co-ordination between designer, architect and maintenance engineer is critically important at the designing stage.	This paper presents a case for an inadequate design for flexibility and maintainability to emphasises the importance of designing maintenance out. However, it does not show real life cases of good design for better maintenance.	√						√		√							√					√	
(Lee, 2007)	UK	Introducing an “option fee” in the PFI contract, where the public sector pays the private sector for additional unitary payment of the concessional period, is suggested as a way for both parties to take advantage of incorporating flexibilities within the project.	Using the Royal Infirmary in Newcastle-upon-Tyre in Cambridge, UK, as a case study of a PFI development of the National Health Service, a financial valuation is proposed to analyse the cost and rewards of implementing flexibility in the project.	√				√									√						√		

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(Neild, 2008a)	Australia	Numerous case studies on landmark Australian hospitals built since 1974. The hospitals discussed include Coffs Harbour Hospital, NSW, and Sunshine Hospital, Melbourne, and the article provides a good overview of hospital design projects in Australia's past.	Rather than proposing a new system, areas needing change within the existing system are identified and critiqued. It should be read in conjunction with the postscript by the same author to gain insight as to possible future directions in healthcare.	√						√													√		
(Neild, 2008b)	Australia	Hospitals should be looked at as series of events rather than static functions, and their buildings flexible and movable with open spaces. They should have separate contracts for the base building and fit out, as the hospital design can be kept more up-to-date with the fit out design done at a closer time to its actual implementation.	The author compares hospital design to airport and hotel design, noting the lack of advances in the former compared to the other two genres. Recommendations are made which can give a broad understanding of issues challenging contemporary hospital design, but it lacks specific building and design advice.	√				√		√													√		

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(Neufville, et al., 2008)	UK	Flexibility is categorised into operational, tactical and strategic flexibility. The current PFI process in the UK makes flexibility uneconomical as necessary renovations during a building's life-cycle are often outside the initial contract scope and hence become extremely expensive.	Hypothetical cases are developed to illustrate design and masterplanning options, with probability taken into account for their cost/benefit analysis. The proposed solution is for a PPP to develop beyond a client-contractor relationship into a real partnership that equally shares its risks and rewards.	√				√		√							√	√				√	√		
(Nitch, 2006)	USA	Flexibility means accommodation of the technological change and growth of medical equipment and medical practice. Flexible hospital is designed with an orderly, regular and predictable framework. De-centralisation is a key feature.	This thesis is based on a design proposal for a heart building. It provides useful concepts and design plans. However, it is not certain if the proposal was fully accepted by the hospital.	√						√					√								√		

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(Odegard & Justison, 1996)	USA	Advice is given on planning and design. Planning includes making projections about the future by describing a series of events and their likely occurrence; design involves looking at how the site, structure, services and space plan are developed.	Although generic in nature, the strategies are practical and categorised into clearly defined topics and subsets, which are easy to understand and provides an excellent overview to planning and designing for flexibility.				√		√	√	√														√
(Olson, 2008)	USA	Some of the key elements identified are an adaptable building infrastructure, modular planning and functional adaptability. Case studies include the Northwestern Memorial Hospital, Chicago, Illinois and the Arrowhead Regional Medical Center, Colton, California.	This article looks at the importance of an adaptable design to keep up with the rapid change in USA. Whilst useful in identifying the case studies, it does not go into enough depth; to extract useful information from the case studies however, they would have to be researched further.				√			√				√	√	√			√				√		

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(Pati, Harvey, & Cason, 2008)	USA	Nine physical needs for flexibility were identified, seven of which correspond to the flexibility to adapt to new operational circumstances. Each of these needs is discussed in terms of operational issues, environmental response and implication for inpatient unit design.	An end-user evaluation in the form of semi-structured interviews is conducted at 6 hospitals across USA to determine how flexibility can improve staff performance efficiencies. The findings provide useful design advice not least owed to the thoroughness of the research.	√						√		√		√		√				√			√		
(Potter, 2008)	UK	Structural flexibility is vital in designing primary healthcare facilities. This is because of the care delivery changes from secondary to primary care. This shift demands significant expansion and structural changes.	Based on actual cases, this paper shows how new primary healthcare facilities in the UK are being designed in consideration of future flexibility. It contains useful principles in practice for flexibility.		√					√				√									√	√	

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(Pressler, 2006)	USA , CHILE	Provides an overview of flexibility, cost benefits, and definitions. Room design, modular systems, acuity adaptable rooms, shell space, and site master planning. Two case studies included: Methodist Hospital, Arcadia, California, and Clinica Las Condes Medical Centre, Chile.	Good general overview of benefits, including costs, and examples of flexibility in hospital design - especially difference between short term and long term flexibility. Case studies are brief, but practical design elements are discussed, and include floor plans.	√					√	√	√						√						√	√	
(Rechel, et al., 2009)	UK	The authors identify three distinct hospital functions - intensive care facilities (the “hot floor”), hotel function (low-intensity nursing) and office facilities (administration, outpatient units etc). Hospitals are viewed as settings for managing processes, in terms of systematic care.	Based on literature research and nine case studies across Europe, this article extrapolates generalised lessons regarding building flexibility and lifecycle assessment approach. The issues discussed can be used to anchor disparate case studies to common themes.	√						√		√		√		√							√		

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(Reiling, et al., 2004)	USA	The St Joseph's Community Hospital, Wisconsin, was designed with the explicit goal of enhancing patient safety through facility design innovations. Operational flexibility, expandability and the standardisation of room layout were adapted as some of the facility design principles.	The project team identified specific precarious hospital events and established design principles to create an environment that minimises those events. Whilst flexibility of the facility was not the main design driver, allowing for operational flexibility and standardisation has impact on ensuring patient safety.	√						√						√							√		
(Sadler, et al., 2006)	USA	Based on a hypothetical business case study, it is financially viable to incorporate evidence-based building design with due consideration of its relevance to the business, quality and safety impact on patients, families and staff.	Design features illustrated in previous chapters of the book are applied to a hypothetical Fable Hospital in a financial analysis. Although based on a "conservative estimate", these cost estimates should be viewed with caution as it is hypothetical and based on examples from USA.	√				√		√							√						√		

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(Scalise, et al., 2004)	USA	Whilst standardised rooms are seemingly logical from a built environment perspective, healthcare workers are sceptical about its effects on staffing. Several patient-focused advances in ICT are also discussed.	Several recent American hospital case studies are presented along with interviews with personnel at hospitals are used to illustrate the point. The brief article identifies case studies that may assist further research.	√						√		√		√	√	√							√		
(Scott, 1993)	USA	Flexibility is the answer when the future is uncertain. Technology is driving much of the redesign.	This paper is based on a survey of healthcare design and construction. 213 respondents are made up of executives of design and construction firms.	√						√	√			√	√									√	

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(The American Institute of Architects, 2005)	USA	Examining changes to the case study in its 30 years of operation, it was found that many of the provisions for flexibility and adaptability were not utilised due to changes in administration and political and economical conditions, but the concepts were developed in the architects' subsequent projects, including the William Osler Health Centre in Brampton, Ontario. The study also noted a potential conflict between 'the expression of the idea of flexibility in hospital design and the expression of a healing environment'.	This design-centric article discusses theories and approaches of "*Hospital planning for change*" by Zeidler Partnership Architects, leading healthcare architects in Canada. McMaster Health Science Centre in Hamilton, Ontario (built 1972). Flexibility is maximised through using the concepts of modularity, full or partial interstitial spaces and the separation of functions.	√						√	√	√												√		

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(Thiadens, et al., 2009)	Norway	The project team devised a new concept infrastructure which they named "Industrial, flexible and demountable" (IFD) design. Measures employed based on these principles are successful in overcoming the gap in expectation between existing structure and new medical demands.	The article is a case study on the Martini Teaching Hospital in Groningen, Netherlands, and extensively describes the hospital's many flexible design elements, how the model of care is supported by the proposed physical infrastructure, and what the financial implications are.	√					√	√		√	√	√									√		
(Valen & Larssen, 2006)	Norway	Six hospitals in Norway ranging in age are selected as case studies to explore how well they adapt to changes over the years. Good examples of flexible design allows for future expansions and interchangeability between rooms.	The article provides valuable insight into both principles and specific elements that contribute to an adaptable hospital but design plans will need to be studied to appreciate the design implications of these findings.	√					√	√	√	√		√									√		

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(Verderber & Fine, 2000)	UK	Detailed studies on flexibility issues include interstitial spaces, modular systems, and strategies for horizontal expansion. Numerous case studies cited, including the McMaster University (1972) and Southeast Memorial Hospital (1983-85) in Houston.	Whilst not particularly focused on flexibility in hospital design, it explains how varying design and planning issues has been dealt with in the past. Places flexibility in hospital design in its historical and cultural context and is suitable as background reference.	√	√	√	√		√	√	√	√	√	√		√				√			√		
(Vos, et al., 2007)	Netherlands	Hospital floor-layout designs are examined in terms of fit and flexibility using a simulation model. An outpatient clinic 'airport' floor-layout design for a new hospital [St. Antonius Ziekenhuis] is examined using the model. A more flexible design will include decentralized waiting areas and standardized consultation rooms.	Comprehensive article that argues floor layout design affects flow and operational efficiency. Design elements that can be extrapolated are included through the case study and authors' solutions to increase flexibility.			√				√				√									√	√	

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				Hospital (general, psychiatric)	Primary care centre	Ambulatory care	Other / unspecified	Funding/tendering	Site master planning	Building design	Construction	Facility management	Other	Model of care	ICT	Patient safety	Affordability / Cost	Policy	Sustainability / ESD	Literature review	RCT	Quasi-experimental	Case	Expert opinion	Anecdotal
(Westlake Jr, 1995)	USA	SAFE elements for health care facility design are *Strategy*, *Assessment*, *Flexibility* and *Efficiency*. Time frames defined and then discussed in terms of flexibility design elements include shell space, modular design, master planning, mix of core and soft areas, and building elements for future vertical and horizontal growth.	In depth article outlining SAFE paradigm. Useful practical design elements are included. No case studies. Diagrams included, illustrating design elements. Article is quite old but still relevant as generic design strategies are explained.			√		√	√	√	√	√		√	√									√	
(Worthington, 2008)	UK	Looking beyond the hospital - a care network could be groups of buildings where some are owned, some are leased, some are beds in the homes of the patient. All these strategies should be implemented at the briefing stage and continuingly evaluated.	It is argued the issues we currently face regarding hospital design is akin to those of office design 30 years ago. Noting that change is both physical and organisational, instances are cited where commercial organisations increase real estate flexibility by owning part of their workspace and renting the rest.				√	√	√	√														√	

Nationality reference's country of origin
Facility the type of healthcare asset discussed
Parameter what they are discussing in the article
Context why is flexibility and adaptability stated as necessary
Method research method employed
Case study case stud(ies) discussed (ref. Case studies list document)

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