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

ANNOTATED BIBLIOGRAPHY

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Barlow, J., & Koberle-Gaiser, M. (2009a). Delivering Innovation in Hospital Construction: Contracts and Collaboration in the UK's Private Finance Initiative Hospitals Program. *California Management Review*, *51*(2), 126-143.

The relationship between Private Finance Initiative (PFI) and innovation in the design of healthcare infrastructure to enable future adaptability is explored. Under PFI - a form of Public Private Partnerships (PPP) - several private sector partners form a consortium - a special purpose vehicle (SPV) - to deliver capital assets and services to a National Health Services (NHS) hospital trust for a fixed period. The research found that the government's incentive to implement PFI - the transferral of risk onto the SPV - led to a bidding process that is focussed on the distribution of risk to the detriment of potentially innovative design. Although an adaptable design has "sales factor" it went against the general risk-adverse attitude within the PFI consortia. It was even suggested that there is a disincentive to plan for adaptability because the SPV could achieve additional income through future alterations. Nonetheless, measures for future design adaptability have been included in all case study designs, although none of these measures were considered particularly innovative. One suggestion for soliciting innovative design outcomes is to have the design stage separate from the subsequent tendering process so that innovation is not hindered by financial constraints.

Barlow, J., Koberle-Gaiser, M., Moss, R., Noble, A., Scher, P., & Stow, D. (2009b). *Adaptability and innovation in healthcare facilities: Lessons from the past for future developments*: The Health and Care Infrastructure Research and Innovation Centre

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. It is found that the PFI process stifles innovations for several reasons, namely: tendency for poor project communication; risk aversion and the overly tight control of capital spending. The report found there is a lack of serious data and analysis relating to adaptability and flexibility in NHS hospitals and additional research on the topic is needed.

Bjørberg, S., & Verweij, M. (2009). Life-cycle economics: cost, functionality and adaptability. In B. Rechel, S. Wright, N. Edwards, B. Dowdeswell & M. McKee (Eds.), *Investing in Hospitals of the Future* (pp. 145 - 166). Copenhagen: World Health Organization.

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. The emphasis on new hospitals is shifting towards building the "optimal facility" rather than grandness or prestige, and as such the ability of hospitals to adapt to fluctuations in the market will be highly regarded. A Dutch design competition entitled "Future Hospitals: competitive and healing" explored the aforementioned concepts. The winning scheme, "Core Hospital" by Venhoeven/Guthknecht, examined functions that were absolutely essential for inclusion in the core hospital building and found that only 50% of the traditional floor area was needed. The functions to be included in the core are closely related to the "hot floor" (e.g. operation rooms, diagnostic imaging and intensive care facilities) functions. This approach enables hospitals to be located in inner city areas where space is limited, with the core hospital in the centre and ancillary support functions scattered around disparate sites nearby.

When undertaking a financial analysis, a lifecycle approach needs to be applied, where costs are separated into management, operation, maintenance, development and service functions and combinations thereof, with depreciation and discounted cash flow formulas applied. Functions should be 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. This SLP approach is applied to an anonymous case study in the Netherlands. Five different redevelopment scenarios are costed to show the effects of lifecycle analysis, and in this instance, the scenario with the least initial cost will have the greatest annual costs during its operation, making it the most expensive overall.

Briggs, P. J., & Barnard, C. (2000). The New Northwestern Memorial Hospital: Planned, Constructed and Operated Through the Patients First Philosophy. *Journal on Quality Improvement, 26*(5), 287-298.

The New Northwestern Memorial Hospital in Chicago, USA was opened in May 1999 and focuses on meeting patient needs in the building layout and design, leading to ease of navigation, consolidation of services and redesigned processes. This article outlines the planning and construction phases for the hospital as well as some preliminary findings in the operational phase. Some patient centred strategies are highlighted, including specific flexibility measures for the radiology/diagnostic imaging areas and operation rooms, with seemingly good results. These lessons can potentially be transferred to another site but since the article is published less than a year after the completion of the hospital and the authors are employees of the hospital - the Manager of the Patient Representative Department and Director of Quality Strategies - the objectivity and applicability of these measures will need to be verified.

Building Design Partnership. (2004). Learning from French Hospital Design. Retrieved October 6, 2009, from http://www.bdp.com/Documents/BDP-LearningFromFrenchHospitalDesign.pdf

As of 2002, French hospitals cost one half to two thirds that of UK hospitals per square metre and their building services cost less than half of UK hospitals. The French also demonstrate higher overall performance including a greater faith by the public in the national health system, 50% more beds available per capita, and all rooms being single rooms with access to daylight. 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. The findings list some key differences between the two countries, the most notable of which includes the "contractor-led" approach the French takes and the differences in their national health policies. Contractors are in charge of the detailed design and construction stage, which leads to a focus on simple, low cost construction technology and methods. As French policy dictates that all habitable rooms are to have daylight access with outlook to a courtyard space, French hospital buildings also tend to have a narrow envelope facing out onto a landscaped area.

Bush, C. A., Reisman, D., Anstine, L., Gallaher, C., & Davis, R. (2005). The Ohio State University Richard M. Ross Heart Hospital: Design and Function of a Specialty Hospital in the Academic Environment. *American Heart Hospital Journal* (3), 120-127.

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. 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. In this case, the hospital's capacity for flexibility relates directly to patient satisfaction as well as physical expandability - structurally the facility is designed to allow the addition of patient floors above the existing roof. User satisfaction has been met and/or exceeded for the first 2 months of operation but it is unclear from the article whether subsequent studies are being conducted to monitor the hospital's subsequent performance.

Cama, R. (2009). *Evidence-based Healthcare Design*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Medicine has long benefited from research based on systematic observation and experiment to derive at a desired outcome. 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 tracing design objectives to outcomes. A good example involves the location and orientation of a hand-washing sink in an emergency exam room that will encourage caregivers to begin the task of hand-washing while immediately engaging in conversation with the patient, hence improving hand-washing compliance as well as improving staff-to-patient communication. Whilst the concept of evidence-based design is not new, it is not yet widely implemented, mainly due to a lack of accessible knowledge base and a general fear of change on the part of clients and design professionals.

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. Some of the ideas are timeless - for example dealing with human interaction and communication problems when trying to adapt to the new system - whereas some ideas are quite current, such as where to best find information online. The key message is that a rigorous and systematic approach needs to be applied to the design process, where all potential users are taken into consideration and design concepts and elements are tested, and the knowledge gained in the process shared to create a solid knowledge base.

Datta, M. S. (2000). High Touch, High Tech, High Flexibility: Reducing Obsolescence in Patient Care Environment. *Design & Health World Congress.* Retrieved 29 September, 2009, from http://www.designandhealth.com/Media-Publishing/Papers.aspx

Recent trends in hospitals are studied from the perspective of the patient, the physician, the nurse and the family. The study notes the diminishing bond between the above groups over the years as healthcare systems become more complex. The solution is a "Universal" nursing unit based on the concept of designing computer hardware, where the components are easily adaptable. One of the main goals of a Universal model is to enhance the flexibility of the infrastructure; but also to maximise the contact between the patient and physician. Several building elements and design concepts are identified, including the use of internal partitions and modular structural grids. These ideas are then applied to specific physical (hypothetical) examples, making the information easy to interpret.

Diamond, S. (2006). *R&D Project B(01)16: Rethinking hospital design - A research study commissioned by NHS Estates*: Department of Health.

Healthcare asset design is influenced by industrial and operational drivers in a similar way as occurs for design in the commercial sector, yet hospital development has not experienced the level of change and innovation found amongst other building sectors, partly due to a legacy of old buildings, a lack of investment and consequent lack of expectations. The various drivers for change are explored, with particular emphasis on recent advances in information technology and the way it has altered the way people work. By studying emerging healthcare trends and how users are likely to use the space, and learning from other sectors as well as existing operating hospitals, key design principles are extracted to compose future-proof solutions for new and planned hospitals. Exemplary hospitals that were identified by this study as pursuing innovative design solutions are The Maritime Hospital, Barcelona, Spain; The National University Hospital, Oslo, Norway; Nuremberg Hospital, Nuremberg, Germany; Alcorcon Hospital, Madrid, Spain; Trondheim Regional Hospital, Trondheim, Norway; Aarhus University Hospital, Skejby, Denmark; Groningen University Hospital, Groningen, the Netherlands; Kaiser Permanente, USA, and ACAD, Central Middlesex Hospital, London, UK.

Doiel, M., & Loharikar, R. (2003). Facility profile. Chicago hospital can flex for change. *Health Facilities Management, 16*(11), 10-11.

A case study of the newly constructed John H. Stroger Jr. Hospital, Chicago, USA which opened in 2002, and was designed by Cook County Hospital Design Group. The hospital is very large - three football fields long and one football field wide. Flexibility was built into the hospital by two methods: adapting a typical 30 foot by 30 foot column bay module design, and not smaller or irregular column bays meant that the different departments can assimilate space as needed because the space is not individually tailored to one type of department. Clinical clustering of outpatient clinics with similar criteria allows the spaces to expand or contract as needed on a day to day basis.

Eagle, A. (2006). The future is now. Flexibility and expandability drive hospital project. *Health Facilities Management, 19*(4), 14-20.

A case study of the newly constructed Banner Estrella Medical Center, Phoenix, USA, opened in 2005, and was designed and constructed by NBBJ, The Orcutt/Winslow Partnership and DPR Construction. The hospital is a part of Center for Health Design's Pebble Project, using evidence based design to improve patient outcomes, examples including all private rooms, enclosed medication rooms, and a family bed in each room.

The hospital was designed for future growth. The site masterplan of the hospital was 'constructed backwards' - the built hospital covers ½ million square feet and has 172 beds in one patient tower, however the 50-acre site will eventually contain a 1 million square foot, 600 bed, 3 tower hospital. The central spine contains fixed major vertical/horizontal circulation routes, and bed towers, diagnostic and treatment services are attached to the spine. The electrical backbone is only at 15% capacity, and fibre for IT and sewer system also allow room for growth. All patient rooms, a standardised 220 square foot rectangle shape, will eventually be acuity adaptable. All four patient floors have the same consistent design, creating familiarity and lessening errors, and also provide the benefit of being easier and quicker to build - architectural drawings, construction, mechanical, electrical and plumbing were all more efficient, therefore financially beneficial.

Eagle, A. (2007). Embracing change. Flexibility is key to design of suburban hospital. *Health Facilities Management, 20*(3), 12-17.

A case study of Clarian West Medical Center, Avon, Indianapolis, U.S.A., opened in 2004, built for flexibility by large universal patient rooms, acuity adaptable rooms, shell space for additional rooms, standard materials, furnishings and colours, oversized clinical pathway, and a masterplan designed for growth. Makes the point that universal rooms added to construction costs, but this is outweighed by the benefits. This case study provides a good example of flexibility in practice as two years after the facility was built the intensive care unit was re-positioned with no construction costs.

Farrelly, E. (2002). Taming St Vincent's. *Architecure Australia, 91*(4), 58-63.

St Vincent's Healthcare Campus in Darlinghurst has been redeveloped under the idea of 'growth-and-change' by the late 1990s. Emphasis on prevention and 'ambulatory' care has resulted in the spatial balance between a hospital's three main parts; wards, treatment and diagnostic, and the 'hotel' (kitchen/laundry) component. Major changes include reduction in the size and number of wards, extended treatment and diagnostic space, and increased size of operating theatres due to their technological requirements. The open-ended corridors allowing extension but also inviting light and street-views, the thirty percent over-sized ducts and risers, the fully accessible interstitial floors to provide universal wall-less cabling and servicing, and the non-specific room types are also key features of flexible design.

Gallant, D., & Lanning, K. (2001). Streamlining patient care processes through flexible room and equipment design. *Critical Care Nursing Quarterly, 24*(3), 59.

Provides a theoretical and practical overview of flexible patient room design, including history, benefits and case studies. Designs discussed are flex unit, universal room, acuity-adaptable rooms, and single stay units. Benefits include: not transferring patents saves time (on average of 3.5 hrs) and costs; provides continuity of care by caregivers; provides on the job training for staff and career opportunities, leading to staff retention. Designs have been difficult to implement in large inpatient settings because large tertiary hospitals have complex and unstable patients; requires upgrading medical-surgical staff skills; long-term flexibility not attractive to CEOs on short tenure ('return on investment'). Stable and manageable patient groups are better suited to acuity adaptable rooms than others e.g. ICU coronary medical patients. Case studies examined are: Celebration Health, Orlando (universal room design leads to reduction in average lengths of stay and nursing hours per patient day); MedCath (universal room design); Loma Linda University Medical Center, California (retrofitted single-stay unit leads to reduction in average length of stay); and Methodist Hospital (Clarian Health Partners) in Indianapolis, Indiana (retrofitted acuity-adaptable rooms). Reasons for the success of these examples are discussed (clinical population, scale), providing usable information for hospital planners. The authors are from Hill-Rom company (a manufacturer of medical technologies) so the objectivity of this article would need to be verified.

Geiser, S. (2004). *Open Building in Health Care Architecture: The Case of the INO Project in Bern, Switzerland.* Paper presented at the The 10th Annual Conference CIB 104 Open Building Implementation.

Renovation has been undertaken to the west wing of the Insel Hospital in Bern, Switzerland. A separate (discrete) planning method has been applied to increase the service life of the building and reduce the follow-up costs. This method takes the different service lives of the individual components of a building into account. Thus, construction is divided into three discrete system levels; primary, secondary and tertiary systems. The primary system (building shell) with a service life of 50-100 years is an unchangeable long-term investment. The secondary system with a service life of 15-50 years contains mid-term adaptable parts, which comprise interior walls, floors, ceilings, and technical access etc. The tertiary system with a service life of 5-15 years can be changed without major structural alterations. Unfortunately, this paper does not present the detailed design plan for future adaptability and the outcomes of the renovation. However, it is, at least, suggestive that health facilities can be divided into more or less flexible/adaptable parts. Particularly, the secondary system, which comprises finishing work (interior walls, finish floors, ceilings), building services installations (central control rooms and technical access), and internal structure for vertical and horizontal movement and transfer systems, is key for design for flexibility.

Gupta, R., & Marshall, D. (2005). Technology Transfusion. *Consulting - Specifying Engineer, 38*(1), 30-35.

Greater emphasis is placed on the function of mechanical and electrical infrastructure. Three US hospitals have successfully integrated technology into adaptable design and low-cost maintenance. Northwestern University's Galter-Feinberg replacement hospital in Chicago can be easily modified by installing identical HVAC systems in each area of the hospital, which was made possible by the engineers' involvement in the design. It was adaptably designed so that administrative offices could be changed into surgical beds. Prentice Women's Hospital, part of the Northwestern Memorial Medical Center Campus, is a totally digital hospital from its ORs and imaging facilities to its patient rooms and building control systems. In consideration of flexibility, each floor has at least one dedicated Remote IT room that is large enough to consolidate servers. Rush University Medical Center has flexible HVAC systems. It contains two large central systems for chilled water, steam and air systems.

Harvey, T. E., & Pati, D. (2008). Functional flexibility: nine attributes of adaptable hospital spaces. *Health Facilities Management, 21*(2), 29-34.

This is a magazine-style version of the following article included in the annotated bibliography below:

> **Pati, D., Harvey, T., & Cason, C. (2008). Inpatient Unit Flexibility: Design Characteristics of a Successful Flexible Unit. *Environment and Behavior, 40*(2), 205-232.**

The nine attributes identified by a survey of 50 administrators and clinicians by architectural firm HKS are 1) multiple division and zoning opportunities, 2) peer lines of sight, 3) patient visibility, 4) proximity of support, 5) resilience to enable the moving, relocating and interchanging of units, 6) ease of movement between units and departments, 7) multiple administrative control and service expansion options, 8) flexible support core elements and 9) expandable support core. The authors conclude that from an operational perspective 'adaptability' is the most preferred form of flexibility - meaning that changes can be made without construction. A design plan of McKay-Dee Hospital Center, Ogden, Utah, is used to illustrate design that allows for movement between units and

expansion options. The article is easy to read as an abridged version of the aforementioned scholarly article, with "What works" summaries after each attribute to provide practical design solutions, and the design plan is also useful to illustrate design features.

Health Care at the Crossroads: Guiding Principles for the Development of the Hospital of the Future. (2008). Retrieved October 24, 2009, from http://www.jointcommission.org/NR/rdonlyres/1C9A7079-7A29-4658-B80D-A7DF8771309B/0/Hosptal_Future.pdf

Principles to guide the development of hospitals for the future are required. In America, the Joint Commission appointed an expert Roundtable to evaluate the current health care environment and identify the elements of the future hospital to meet the needs of patients and the public. The issues discussed include socio-economic trends, technology, the physical environment of care, patient-centred care values, staffing challenges and the design implications in dealing with the above. The report identifies flexibility as one of the principles to guide design and provides a six-point description of the topic: master planning strategies, loose-fit design, adaptable flexibility, convertible flexibility, robust utilities and plug-and-play infrastructure. The points are in the order of a hospital's lifecycle, that is, from strategic planning through to renovations and expansions. The article provides a short overview to understand the challenges of hospital design today, but does not provide details that can enable better design.

Hendrich, A. L., Fay, J., & Sorrells, A. K. (2004). Effects of Acuity-Adaptable Rooms on Flow of Patients and Delivery of Care. *American Journal of Critical Care*(13), 35-45.

The increase in the last decade of "low-risk monitored patients" has led to the considerations for flexible rooms for patients who require progressive care. The proposed solution is the acuity-adaptable room, where progressive and critical care could be provided in the same setting. The paper uses the Methodist Hospital, Indianapolis, as a case study. The new Cardiac Comprehensive Critical Care unit contains 56 acuity-adaptable rooms and was opened in 1999. Each room is 36m2 and consists of three main areas: the family zone, the patient zone and the caregiver zone. Research confirmed that acuity-adaptable rooms allow care for more patient days in fewer beds. Transport of patients decreased by 90% and medication errors decreased by 70%. The Critical Care unit was recognised by the American Association of Critical Care Medicine, and the American Institute of Architects as the critical care award winner and it has established new standards for high-tech, holistic care.

Jensø, M., & Haugen, T. (2005). *Usability of Hospital Buildings: Is Patient Focus Leading to Usability in Hospital Buildings?* Paper presented at the Facilities Business and its Management.

Planning and designing the St. Olav's Hospital in Trondheim, Norway, is a large ongoing redevelopment project with a pronounced objective of achieving high degree of patient focus. This project is reviewed from the point of 'usability of hospital building', which is closely associated with physical and organisational adaptability over a period time. The principles of 'patient in focus' and 'usability of building' found a design solution from a decentralised hospital with smaller, partly autonomous units in separate buildings or as integrated centres in independent units. Each centre represents a self-sufficient unit. Patient transfers are minimised within the centre for a necessary treatment under a more humane and dignified atmosphere. Future structural changes are assumed

to be fulfilled within the centre, with minimal consequences for the rest of the hospital. 'General centre' is the key concept of this project. As a prototype for the development and design of each centre, it provides basic principles for building structure, communication, organisation, functional division, volumes, exterior facades, use of materials and so on. Under this concept, functions are identically located on the floor plans in each centre, and functions belonging to one centre can be easily expanded into the adjacent centre.

Johnson, T. K. (2004). How trends will affect health care facilities design and construction. *Health Care Strategic Management, 22*(1), 15-17.

Facility development planning must give careful consideration to trends in health care delivery. Key trends, which drive facility renovation and expansion, include increased utilisation of health care services among the baby boomer population, technological and pharmaceutical advances, and increasing patient demand for responsive health care. Flexibility design features include universal design for patient rooms, increase in size of patient rooms, large blocks of space with adequate floor-to-floor heights that are easily convertible for different uses. Key areas within which reconfiguration and expansion might occur include nursing units, emergency department, surgery, imaging, and ambulatory services. Brief design trends in each area in conjunction with health care delivery change are presented in this paper.

Jonassen, J. O., Klemenic, R., & Leinenwever, M. (2001). Health Facility Flexibility and Humanity. In A. Dilani (Ed.), *DESIGN & HEALTH II - The Therapeutic Benefits of Design*. Stockholm, Sweden: Design and Health.

Recognising changes are prompted by advances in technology and emerging trends in healthcare, whilst fundamentals such as the need for people movement, the delivery of supplies and removal of waste, and humanistic needs for sunlight and air remain constant as ever, a flexibility strategy for health facility design is developed. The strategy addresses the pragmatic requirements of a hospital including people movement, mechanical / electrical distribution and integrated infrastructure, giving diagrammatic examples for possible modules and systems. 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. Although some design aspects will differ from one jurisdiction to the next depending on their legislative requirements, the article provides illustrative insight on a generic level.

Kendall, S. (2005). *Open Building: An Architectural management paradign for Hospital Architecture.* Paper presented at the CIB W096 Architectural Management.

This paper reviews the same facility as above, the Insel Hospital in Bern, Switzerland, focusing on the same aspects of innovative management method, three distinctive but coordinated construction/management systems. 'Distributed design management' replaces the term 'separate (discrete) planning method.' However, this paper presents more detailed design processes and visualisations. This hospital is described as the first medical facility in the world where 'open building' management principles were applied to the design of a large medical complex. Design for the

primary system, which includes site locations, building envelope, structure system, and interior logistics , is characterised with a floor plan with 8.4 square metre structural grid and the placement of 3.6 square metre 'punch through' opportunities which allow a possibility of vertical penetrations at any location in the floor plate for vertical circulation, mechanical systems, and light shafts. The secondary system, which is associated with interior walls, fit-out system, floor covering, and ceilings, considers the following attributes; technical performance, serviceability, and architectural attributes.

Kliment, S. (Ed.). (2000). *Building Type Basics for Healthcare Faciliites* (1 ed.). New York: John Wiley & Sons, Inc.

This book on healthcare facilities design was one of the first in Wiley's "Building Type Basics" series, and is intended as a one stop, quick reference guide for architects, consultants and their clients when starting up a project. It recognises the need for flexibility in order to keep up with new technology, which creates unknown space and connectivity requirements. The four chapters are organised by different hospital functions: perspective (overview), ancillary departments, inpatient care facilities, and ambulatory care facilities. Examples are used to illustrate a point, sometimes based on a real life case study, sometimes generic or hypothetical. The case studies include Maine Medical Center, in Auburn Maine (1998) and Arrowhead Regional Medical Center. Data include detailed financial analysis, typical departmental space allocation, indices such as Yale University Traffic Index Factors showing percentage of travel time from nursing staff travel links such as patient room to nurses' station and utility room to medical clinic and numerous diagrams. Although flexibility it 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.

Kumar, P. (2000). Design and Care in hospital planning. *Design & Health World Congress.* Retrieved 29 September, 2009, from http://www.designandhealth.com/Media-Publishing/Papers.aspx

Design of healthcare facilities needs to have a focus on "total care", which is inclusive of the needs of patients and their accompanying relatives and friends and that will reduce stress for all concerned. At the same time it must remain financially viable. Some key design parameters identified are the evaluation of space allocation for "super-speciality hospital" and "multi-speciality referral", which were implemented in the Oncology Centre at Jaipur and Cardiac Centre at Mohali.

Lam, K. C. (2007a). *Sustainable Hospitals with Growth and Change*. Paper presented at the Conference on Sustainable Building South-East Asia, Malaysia.

A hospital building site must be large enough for all planned functional requirements and also for any possible expansion. Sufficient allocation of site is a prerequisite for future development and additional 50-60% of the foundation area, at least, is recommended for any possible expansion. The ratio of the length and width of the hospital site should be about 4:4.5 or 2:2.5. A big square site is better than a long and narrow one. The hospital should be located in the middle of the site, leaving 30-50% at both sides so that new buildings can be added.

Lam, K. C. (2007b). *Taking Steps Towards Sustainable Hospital Buildings*. Paper presented at the Conference on Sustainable Building South-East Asia.

Sustainable building care can be achieved by lean design with appropriate technologies, low maintenance but higher durability, adaptability, and reusability. A large 20 year old teaching hospital in Hong Kong had to be rebuilt due to inadequate design for maintenance services. Maintenance issues need to be addressed at the design stage to ensure that proper maintenance is fully integrated into a building design. Planning sustainable buildings require a team approach to coordinate maintenance services with the building envelope and structure. Designing maintenance out is the solution for sustainable building, and the following are relevant considerations; fully integrated and coordinated design so that each service system can be installed and maintained with ease, simple design solutions which give better durability, early design audits in accordance with operation and maintenance requirements, ensuring that replacement or refurbishment is possible without breaking the building, checking whether any equipment becomes obsolescent before the end of the life cycle of the building, provision of suitable access for maintenance work, and attention to safety issues during operation and maintenance.

Lee, Y. S. (2007). *Flexible Design in Public Private Partnerships: A PFI case study in the National Health Service.* Unpublished Masters Dissertation, University of Cambridge, Cambridge.

PPP contracts need to have flexibilities explicitly set out at the beginning of the project when contractual conditions are being negotiated. This paper proposes managerial ways of considering flexibility systematically using the “OUF Matrix” - Operational Matrix, Uncertain Events Matrix and Flexibility Matrix. From these matrices a financial valuation method is proposed and applied to the Royal Infirmary in Newcastle-upon-Tyre in Cambridge, UK, as a case study of a PFI development of the National Health Service. The financial valuation analyses the risks and demands of the project and how each identified flexibility affects the project. In particular, it is suggested that implementing an “option fee” in the PFI contract, where the public sector pays the private sector for additional unitary payment of the concessional period, is a feasible way for both parties to take advantage of incorporating flexibilities within the project.

Neild, L. (2008a). Changing hospital design in Australia. In S. Prasad (Ed.), *Changing Hospital Architecture* (pp. 223-250). London: RIBA Enterprises Ltd.

Set firmly within the Australian context, with numerous case studies on landmark Australian hospitals built since 1974, the author advocates quality design outcomes which he believes are currently diluted by project managers' emphasis on driving time and cost down. 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, Nield identifies areas needing change within the existing system and provides a critique of those. It should be read in conjunction with the postscript by the same author in order to gain a level of insight as to possible future directions in healthcare.

Neild, L. (2008b). Postcript: Re-inventing the hospital. In S. Prasad (Ed.), *Changing Hospital Architecture* (pp. 250-268). London: RIBA Enterprises Ltd.

The author compares hospital design to airport and office design, noting the lack of advances in the former contrasted with the latter. Airports have become large-span, flexible halls or hanger buildings where designers can accommodate many different functions and architectural expressions. Offices evolved from formulated boxes containing hierarchical and static functions to dynamic spaces by understanding how people currently work, influenced by technological advances and cultural changes. For example, more recent office spaces have been altered to place managers within their teams in open offices. From these explorations, recommendations for appropriate hospital design and construction are made. It is concluded the new paradigm for hospital design should be a flexible and movable building with open spaces, rather than using universal grids, where walls have to be knocked down each time the space is refitted. Learning from modern office buildings, hospitals need to be looked at as series of events rather than static functions. Hospitals should also have separate contracts for the base building and fit out like they do in offices, 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.

Neufville, R. d., Lee, Y. S., & Scholtes, S. (2008). *Flexibility in Hospital Infrastructure Design*. Paper presented at the IEEE Conference on Infrastructure Systems

Flexibility is categorised into operational (furniture, internal spaces), tactical ('shell space', such as the design of an operational theatre) and strategic (long-term goals, masterplanning) flexibility. The Addenbrooke Hospital in Cambridge, UK, is used as a base point from which hypothetical examples illustrate how an existing, operating hospital can be designed to be flexible and adaptable to change over the years. It is highlighted that 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. 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, M. P. (2006). *The architecture of enabling technology in the critical care setting: The role of architecture in addressing the health care - technology paradox.* Clemson University South Carolina.

Flexibility means accommodation of the technological change and growth of medical equipment and medical practice. This thesis proposes a design plan that integrates enabling technology for a Heart Hospital located in the Laguna Honda section of San Francisco, California. In order to retain flexibility, the hospital should be designed with an orderly, regular and predictable framework. There are three zones within this hospital; the diagnostic and technology (D&T) zone, nursing or inpatient zone and administrative zone. Decentralisation is the main strategy. Each floor has these three main programmatic components, separated into 'mini hospitals' or 'hospitals within hospital.' The D&T zone is designed with the most flexibility. It has an open and flexible floor plate so that the floors can be added upward and expanded outward. The structural frame of the ever-changing D&T block is column-free and incorporates a scaffold-like system that can quickly accommodate additions and renovations. The double-height floor plates have interstitial space that allows expedient alteration of mechanical and other technological systems. The patient units allow for re-configurability and flexibility by way of a 'patient apparatus', which is able to slide back and forth, pivot open and closed.

Odegard, D., & Justison, P. (1996). Flexible Facilities by Design. *Health Facilities Management, 9(*11), 28-35.

Recognising how market forces are changing the way healthcare is provided, and the need to allow for buildings to adapt to its new environs over time, tactics for planning and design are given. Advice on planning includes scenario planning and making projections about the future by describing a series of events and their likely occurrence; design advice involves looking at how the site, structure, services and space plan are developed. Although generic in nature, the strategies are practical and the topics discussed are comprehensive. The topics are also further categorised into clearly defined subsets that are easy to understand and provides an excellent overview to planning and designing for flexibility.

Olson, D. (2008). Changing hospital design in the USA. In S. Prasad (Ed.), *Changing Hospital Architecture* (pp. 183-222). London: RIBA Enterprises Ltd.

As healthcare facilities go through a process of renewal in the USA, this article looks at the importance of an adaptable design to keep up with the rapid change, caused by exterior influences such as change in demographics and technology. Some of the key elements identified are an adaptable building infrastructure, modular planning and functional adaptability; other concerns include patient safety and sustainability. Case studies are discussed relating to some of the themes explored, such as the Northwestern Memorial Hospital, Chicago, Illinois and the Arrowhead Regional Medical Center, Colton, California. Whilst useful in identifying the case studies, it does not go into enough depth. To extract useful information from the case studies, would require further research.

Pati, D., Harvey, T., & Cason, C. (2008). Inpatient Unit Flexibility: Design Characteristics of a Successful Flexible Unit. *Environment and Behavior, 40*(2), 205-232.

An end-user evaluation in the form of semi-structured interviews is conducted at 6 hospitals across the USA to determine how flexibility can improve staff performance efficiencies. Flexibility is grouped into flexibility to adapt, such as adapting to changing workplace practices; flexibility to convert, such as converting the environment in response to a different occupancy type; and the flexibility to expand, specifically expanding a space for a programmatic function. From the interview responses, nine physical needs for flexibility were identified, seven of which correspond to adaptability needs. Each of these flexibility needs is thoroughly discussed in terms of operational issues, environmental response and implication for inpatient unit design.

Potter, C. (2008). Shift to primary care needs flexible design. *Health Estate, 62*(2), 46-50.

Assura and Abstract Healthcare, a new primary healthcare centre in the UK, is a good example of the application of principles in practice of flexible design. In the UK, primary care is moving from the established single GP practice to complex buildings with a wide range of services. Care delivery moving from the secondary care setting to primary care settings requires primary healthcare facilities to be designed to be expandable and adaptable as a sustainable solution. The new generation

building needs to be designed from the outside in instead of from the inside outwards, establishing a simple framed structure, with appropriate floor to floor heights, grid spacing, service zones, means of escape and institutional floor loadings. Internal fit-out should be designed by mean of non-load bearing partitions. The building design differentiates between "shell and core", moveable and nonessential spaces. The flexible floor place design allows complete internal planning freedom and should ensure good supply of natural light to all areas.

This paper presents another unspecified project on the integrated care centre that to which flexibility planning was applied. Generic working spaces with common room sizes aid flexibility. The sizes might be 5, 10, 15 or 20 square metres. The modules with a simple flexible grid can lead to highly adaptable buildings able to respond to changing clinical pathways. The fit-out can easily be stripped out and reconfigured plugging into the installed services. Circulation needs to be sufficient. At least 30% or 35%, and up to 40% of circulation is sufficient. And floor to floor height is recommended at around 3.9 or 4 metres, which allow main services to be run from the shafts to anywhere in the building.

Pressler, G. R. (2006). Born to flex: Flexible design as a function of cost and time. *Health Facilities Management, 19*(6), 53-54.

This paper sets out to discuss the main issues related to flexibility. Cost benefit analysis is discussed. Time factors are outlined including methods of providing short term flexibility (moving room furniture such as inpatient beds, wall systems for conference rooms, modular office system space) and long term flexibility (acuity adaptable rooms, universal rooms, LDR/LDRP rooms, patient control of their environment, flexible staff working spaces, family space which can be utilized for alternative purposes, apartment/hotel accommodation, key ancillary services (imaging, surgery) placed next to administration areas, or shell space between diagnostic and treatment spaces and site planning). Two case studies are mentioned, one in detail. The nursing control station plan for Methodist Hospital, Arcadia, California, USA, is an example of a flexible staffing model floor-plan. The final design phase of the renovation of Clinica Las Condes Medical Centre (CLC), Santiago, Chile, is analysed for flexibility, mainly through standardised spaces, same-handed rooms, pod design, and shell spaces.

Rechel, B., Wright, S., Edwards, N., Dowdeswell, B., & McKee, M. (2009, 2-3 April 2009). *How can capital investment in European health systems be more effective?* Paper presented at the HaCIRIC International Conference 2009, Brighton, UK.

Based on literature research and nine case studies across Europe, this article extrapolates generalised lessons regarding building flexibility and lifecycle assessment approach, with the aims of improving the effectiveness of healthcare capital investment. 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). Each has varying inherent degrees of flexibility, with the office facilities being the most flexible. Taking a "whole systems perspective" to account for trends and developments in the health system, such as bringing care closer to the patient, the authors propose viewing hospitals as settings for managing processes. The article's approach can be used to anchor disparate case studies to common themes.

Reiling, J. G., Knutzen, B. L., Wallen, T. K., McCullough, S., Miller, R., & Chernos, S. (2004). Enhancing the Traditional Hospital Design Process: A Focus on Patient Safety*. Joint Commission Journal on Quality and Safety, 30*(3), 115-124.

The St Joseph's Community Hospital, Wisconsin, was designed with the explicit goal of enhancing patient safety through facility design innovations. Learning from the nuclear and transportation industries and spacecraft design, the project team then identified specific precarious hospital events and established design principles to create an environment that minimises latent conditions and active failures in the health care facility. Operational flexibility and expandability were incorporated as one of the facility design principles, with the understanding that the hospital needs to allow for change over time. Specifically, however, the standardisation of room layouts was implemented as it allowed for the accommodation of all equipment and supplies needed for patient care, allowing the nurse to remain in the room with the patient, reducing fatigue and increasing time spent with the patient. Whilst flexibility of the facility is not the main design driver, this article shows that allowing for operational flexibility and standardisation has an impact on ensuring patient safety.

Sadler, B., Hamilton, K., Parker, D., & Berry, L. L. (2006). The Compelling Business Case for Better Buildings. In S. O. Marberry (Ed.), *Improving Healthcare with Better Building Design* (pp. 125-143). Chicago: Health Administration Press.

Based on evidence-based design, design features illustrated in previous chapters of the book are applied to a hypothetical Fable Hospital. Recognising that boards and CEO's decisions to fund hospital facility expansion or replacement are based on five key issues, namely: urgency, appropriateness, cost, financial impact and sources of funds; the additional costs and benefits associated with the recommended renovations are evaluated as if for a business case to be presented to the board and CEO. This includes flexible design layouts and acuity-adaptable rooms, amongst other things. It establishes a sixth key issue in addition to the five mentioned above: whether the project incorporated evidence-based building design with due consideration of its relevance to the business, quality and safety impact on patients, families and staff.

Potential savings in areas such as reduced patient falls and increased philanthropy are based on data from Pebble Project partners such as Clarian Health Partners' Methodist Hospital, Indianapolis, and Children's Hospital and Health Center in San Diego, California. Unsurprisingly, the research shows significant first-year savings and revenue gains for the implementation of the proposed design changes. It is argued that the financial analysis is realistic as it is based on a "conservative estimate", however as it is hypothetical and based on examples from the USA, these cost estimates should be viewed with caution.

Scalise, D., Thrall, T. H., Haugh, R., & Runy, L. A. (2004). The Patient Room. *Hospitals and Health Networks, 78*(5), 34-38.

Advocates standardised rooms where the layout of equipment and furniture is identical, producing a "plug-and-play" environment that is easy to familiarise for staff. Drawing from interviews with personnel at hospitals that have implemented this scheme, the research shows that whilst seeming logical from a built environment perspective, healthcare workers are sceptical about its effects on staffing. As one hospital CEO stated: "The acuity-adaptable room assumes a nurse is a nurse is a nurse. That view is badly flawed…", pointing out acuity-adaptable rooms do not account for specialty nursing requirements. Advances in information technology are also discussed with the aim of providing control over their environment and easier access to information for patients. Several recent American hospital case studies are used to illustrate the point.

Scott, L. (1993). Construction key: Keep options open. *Modern Healthcare, 23*(11), 29-36.

Modern Healthcare's 14th annual survey of healthcare design and construction reveals that making room for new equipment and technology is a key factor of flexible design. Flexibility includes the use of separate floors for mechanical systems, which is called interstitial space. Interstitial space makes it easier and less costly to upgrade for future equipment because engineers can reach mechanical systems more easily and the systems have more room for expansion. Each floor has its own mechanical plant room so that floors can be renovated without affecting equipment on other floors. Flexibility also means the inclusion of space for later additions, fibre-optic systems, and a 'mobile technology port' which allows hospitals to test new technology on site before making a costly purchase. Outpatient growth and patient-centred care are also important trends that flexible design should consider.

The American Institute of Architects. (2005). Planning for Change: Hospital Design Theories in Practice. Retrieved 29 September, 2009, from http://info.aia.org/nwsltr_print.cfm?pagename=aah_jrnl_20051019_change

This design-centric article discusses theories and approaches of "hospital planning for change" by Zeidler Partnership Architects, leading healthcare architects in Canada. Focussing on their McMaster Health Science Center in Hamilton, Ontario, (built 1972), it concludes that flexibility is maximised through using the concepts of modularity, full or partial interstitial spaces and the separation of functions. Envisioning future growth, the structure and building services were designed to support the future expansion and even the elevators and stairs were raised an extra level in anticipation of the extension. The interiors were designed as a modular structure separating each part of the building into permanent and non-permanent elements. Examining changes made to the Center in its 30 years of operation, it is found that many measures for flexibility in the original masterplan were not utilised due to changes in administration and political and economical conditions, but the concepts from that project were developed and utilised in their subsequent projects, including the William Osler Health Centre in Brampton, Ontario.

Thiadens, J. G., Kriek, R. J., Afink, G. H., Burger, A. C., & Oosterom, N. J. (2009). Martini Teaching Hospital, Groningen, Netherlands. In B. Rechel, J. Erskine, B. Dowdeswell, S. Wright & M. McKee (Eds.), *Capital Investment for Health: Case Studies from Europe* (pp. (75) - 87). Denmark: World Health Organization.

The Martini Teaching Hospital in Groningen, Netherlands, combines clinical, teaching and administrative functions on a single site. With flexibility, adaptability and durability as starting points for the design, the project team invented a new concept for infrastructure which they named "Industrial, flexible and demountable" (IFD) design. The hospital's many flexible design elements, of how the model of care is supported by the proposed physical infrastructure, and its financial implications are extensively described. The project team used a strategy called "empty chair" in anticipation of the long term changes to the site, and borrowed design and construction principles from industrial buildings which are used to having to adapt quickly to changing circumstances. The new building consists of a narrow block of 60m x 16m, which not only lets more sunlight into the building, but can be easily adapted for office or residential functions in the future without the need for major rebuilding. The cabling and ducting are not routed through the central shaft but placed in insulated pipes outside the facade, thus allowing maximum flexibility for future changes. As a result of the above, developers and property investors see the building's potential value and marketability, hence giving it a baseline value independent of its use as a therapeutic environment. The above measures based on the IFD design principles are successful in overcoming the gap in expectation between existing structure and new medical demands.

Valen, M. S., & Larssen, A.-K. (2006). *Adaptability of Hospitals: Capability of Handling Physical Changes*. Paper presented at the Trondheim International Symposium: Changing User Demands on Buildings - Needs for Lifecycle Planning and Management, Trondheim

Six hospitals in Norway ranging in age are selected as case studies to explore how well they adapt to changes over the years. Hospitals not yet completed are examined for their approach to flexibility in the design concept phase. Adaptability is measured by the spatial ability to meet future needs and good examples of flexible design allows for future horizontal and vertical expansions and inter-changeability between rooms. Benchmarks used for comparison include the use of interstitial floors, the modularity of their grid layouts, the floor heights and load capacities, the design masterplan and its capacity for horizontal and vertical expansion and the planned surplus space. It is shown that when planning new hospitals, considerations for future flexibility are often fought against in terms of added construction costs. For example, standardising room sizes and generous floor heights will lead to increasing volumes which then turn into increased operational and construction costs. As demonstrated by one of the hospitals (Rikshospitalet), the total construction cost corresponds to two or three years of total operating costs, which implies that the priority should be on creating flexible spaces to keep operational disturbances due to renovations and expansions to a minimum.

Verderber, S., & Fine, D. J. (2000). *Healthcare architecture in an era of radical transformation*. New Haven: Yale University.

Past and present international literature on the subject of health facilities architecture is fragmented and with few exceptions, has continuingly been excluded from serious discussions of architectural theory and criticism. This book, written in two parts, aims to synthesise the information available into a unified conceptual framework. Set chronologically, it charts out the history of hospital design from ancient and Renaissance times through to the current patient-centred model of care of the 1990's which coincides with the onset of the information age. It provides comprehensive and meticulously researched accounts of the progression of hospital design, drawing examples and case studies from five continents to give a truly international perspective. Whilst not particularly focussed on flexibility in hospital design, it explains through its studies how varying design and planning issues have been dealt with in the past. Most notably, detailed accounts of "interstitialism" (hospitals designed with interstitial spaces between floors for servicing), modular systems and strategies for horizontal expansion address flexibility. Case studies cited include the McMaster University (1972) and Southeast Memorial Hospital (1983-85) in Houston. Suitable more as background reference material than a quick go-to handbook, the book succeeds in presenting health care discourse in a coherent and accessible manner, placing flexibility in hospital design in its historical and cultural context.

Vos, L., Groothuis, S., & van Merode, G. G. (2007). Evaluating hospital design from an operations management perspective. *Health Care Management Science, 10(*4), 357-364.

The authors explain that the relationship between floor plan design/layout and operational efficiency can deliver flexibility, short throughput times and short displacement distances. The authors define a floor plan that is “flexible and fit” as one that supports the current hospital strategy (between 5 and 10 years) and the future operational requirements, including changed patient mix and technologies, over the lifecycle of the building.

The authors have developed a method of evaluating the flexibility and fit of a floor layout for current functional requirements and future developments. "Discrete event simulation" the "degree of circulation and flow", as opposed to congestion, is used as the measurement. A case study of a new Dutch hospital which will be formed by the merger of two existing hospitals is used to illustrate this evaluation method. The hospital will be newly built, with a proposed "airport" operations management design for its outpatient clinic in an effort to maximise efficiency of space. The clinic's one central waiting area and limited waiting capacity in the different ambulatory departments was found to support the functionality and expected flows of the hospital's proposed logistical concept (that patients will wait to be called from the main waiting area and then be seen immediately be their specialist). However, the evaluation method showed that if the flows change intensity, direction or volume then this will lead to congestion.

The authors conclude that to increase flexibility and fit, the floor plan should have decentralised waiting rooms at the ambulatory departments and standardised rooms, in particular consultation rooms, to reduce the dependency on a proposed logistical concept that will change in the future.

Westlake Jr, P. (1995). Safe for future use? Stages in master planning, programming, and architectural design. *Journal of Ambulatory Care Management, 18*(4), 58-68.

The author, an architect, states that the elements of healthcare facility design can be summed up using the SAFE paradigm: *Strategy*, *Assessment*, *Flexibility*, and *Efficiency*. The article's focus is outpatient clinics, and in particular the examples cover Outpatient Cancer Centers (OCC). Three time-horizons for planning are identified in this model: short term (3-5 years), intermediate (5-10 years), and long term (10 years plus). *Strategy* includes issues of flexibility in relation to site selection chosen for future expansion. Placement within or outside the main hospital site is considered, for example an outpatient centre appended to a medical facility can be used for inpatient or outpatient services in the future, increasing flexibility.

Flexibility and *Efficiency* elements are interrelated. A large part of the article sees the author identifying the key considerations within these elements when planning for the three time horizons. Examples given are: Short term (providing for change without construction or renovation): modular configuration e.g. same room dimensions for office/storage rooms as for examination rooms to allow for possible future adaptability; buffering the "core" program by having pockets of shell, unassigned space and "soft space" situated near high growth areas; building shell radiation therapy vaults next to equipped vaults; not sizing rooms to minimum requirements; grouping programs into zones; open ended corridors for future horizontal expansion; and building for the code requirements of an expanded facility.

Intermediate: e.g. oncology care likely to rise, technological requirements may not be able to adapt to existing areas. Identify future vertical and horizontal expansion and develop foundations and structure to support future loads and extensions; size major utilities, fire lines, elevators, shafts and other vertical penetrations for future expansion; exterior skin can be designed for horizontal expansion (knock-out panels, fenestration, and materials) and the roof designed for vertical expansion in the initial construction phase; 'smart' columns for plumbing and electrical risers for future needs; master planning for future adjoining construction and locate mechanical and electrical equipment where it is least likely to obstruct expansion.

Long term (absolute flexibility for the building to serve completely different functions; this should be a flow on effect of short term and intermediate planning). Considerations for long term planning include: making sure there is space to expand; placement of permanent components such as

entry/arrival/waiting, vertical circulation, radiation therapy walls; master plan must account for horizontal expansion in multiple directions; an outpatient unit (e.g. OCC) must be buffered from other sections of the hospital with growth potential so as not to compete with space.

This article is very theoretical but does identify many design elements that allow for future flexibility and expansion.

Worthington, J. (2008). Managing hospital change: lessons from workplace design. In S. Prasad (Ed.), *Changing Hospital Architecture* (pp. 49-63). London: RIBA Enterprises Ltd.

It is argued the issues we currently face regarding hospital design are 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. Applied to hospital planning, we are encouraged to look beyond the hospital - one scenario is for a network of care buildings where some are owned, some are leased and some are beds in the homes of the patient. All these strategies should be implemented at the briefing stage, where the biggest opportunities for success can be won or lost. Briefing works on many levels and encompasses strategic brief, project brief, and detailed fit-out and operating brief, and top management need to emphasise that it is a continuous process. Evaluation should be used as a way to learn at the beginning of new projects by using the evaluation from the last hospital, not a way to measure project failure at the end of the project.

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