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IMPACT OF MODERN METHODS OF CONSTRUCTION ON HEALTHCARE INFRASTRUCTURE

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The NHS is currently in the middle of an unprecedented building boom. The substantial investment programme estimated at over £11billon involves the regeneration of several existing hospitals and the construction of 100 new ones by 2010 (NHS, 1994). Behind this background, it has been recognised in the vision of the NHS that any effort to improve the quality of healthcare buildings needs to take due consideration of the construction methods to be adopted. At the same time, other factors, such as the involvement of the private sector in healthcare provision through various Public Private Finance (PFI) Schemes; the Latham (1994) and Egan (1998) reports; skills shortages; and the general call for fast tracked solutions in the construction industry have further fuelled the needs for more innovative construction techniques in healthcare sector. This paper provides an overview of MMC with particular emphasis on offsite and modular techniques and their healthcare infrastructure applications. Relevant literature has been reviewed and past projects explored to ascertain the main benefits to be achieved by adopting off-site and modular construction techniques within the context of healthcare infrastructure.

Keywords: construction methods, healthcare, modular, offsite, therapeutic.

INTRODUCTION

The NHS is currently in the middle of an unprecedented building boom. The huge investment programme estimated at over £11 billon involves the regeneration of several existing hospitals and the construction of 100 new ones by 2010 (NHS, 1994). The sheer magnitude of the planned programme and the recognition that healthcare is best undertaken in quality buildings which satisfy a range of complex and often conflicting needs, such as: the flexibility needed to accommodate very dynamic changes in healthcare procedures; the current very challenging issues of cross-infection and MRSA; sustainability issues (such as energy efficiency, natural lighting etc.); and social issues including impact of new facilities on local residents have created a need for more innovative solutions in the provision of healthcare facilities.

At the same time, other factors (for example: greater involvement of the private sector in healthcare provision under various PFI and LIFT schemes; skills shortages; and the general call for fast tracked solutions in the construction industry (Latham 1994 and Egan 1998) have further fuelled the need for innovative construction techniques in healthcare sector. Behind this background, it has been recognised in the vision of the (NHS-Estates, 2005) that any effort to improve the quality of healthcare facilities needs to take due consideration of the construction methods to be adopted and of the benefits to be achieved by adopting Modern Method of Construction (MMC).

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This paper is as a result of an ongoing research into the potential impacts of MMC when used to provide healthcare facilities. In the context of this paper, MMC are considered mainly as Offsite and Modular construction techniques. Although many studies have been carried out into the use of MMC, most have been in the residential and commercial sectors (see for example NAO, 2005; BRE, 2003 and 2006). The paper first provides a brief overview of the needs of the NHS, in terms of Design and Construction specifications. It then proceeds to overview current applications of MMC in the provision of healthcare buildings. This is followed by a discussion on the evaluation of the current impact of MMC on healthcare infrastructure, conclusions are provided at the end of the discussion.

OVERVIEW OF NHS CONSTRUCTION REQUIRMENTS

The importance of good hospital design was expressed, in the NHS-Estates' (2005, p.8) publication: Better Health Building, as follows: 'Good design is not an optional extra, it has to combine fitness for purpose with whole- life costs to deliver value for money…Good quality design will contribute to providing an environment in which patients will be safe and secure…well designed buildings capable of adaptation to meet rapidly evolving medical and technological advances and social change, are more likely to help staff deliver their objectives and long-term best value, good design will also ensure a reduction in defects and more sustainable solutions'. Galvanised by this thinking, the NHS set out what it called its vision which outlined ten principles relating to: Uses; Access; Spaces; Character and Innovation; Citizen Satisfaction; Internal Environment; Urban and Social Integration; Performance; Engineering; and Construction (NHS-Estates, 2005, p.6). In relation to construction strategies and methods, the vision stated 'In construction, standardization and prefabrication will be used to reduce construction time and cost while driving up quality…High quality construction techniques and materials will be selected to minimise maintenance of our building stock…'.

Issues of good design and construction have been well discussed and documented in various CABE (Commission for Built Environments and Architecture, the UK Government's commission for promoting good design and aesthetics for the built environments), with good design being characterised as follows: 'Good Design involves creativity, and it should lead to simplification and to savings in cost. It does not consist of using expensive materials for their own sake or providing lavish areas and volumes. It also takes account of standard products and manufacturing process….it is Design for manufacture rather than manufacture for design' (CABE, 2005, p.8). This position is reinforced by the recent NHS white paper which stated 'With increases in expenditure slowing down after 2008, following record increases over the past few years, the health service will need to focus even more strongly on delivering better value for money' (Gates, 2006, p4).

The above suggest that it is possible to formulate three distinct positions as follows:

- MMC, including *standardization and prefabrication* have an important role to play in achieving the NHS vision of providing high quality therapeutic healthcare environments;

- the construction of cost effective therapeutic healthcare buildings can be substantially enhanced through the use of MMC, such as standardisation, prefabrication and off-site techniques; and
- in the quest for high quality therapeutic environments value for money should not be compromised.

OVERVIEW OF OFFSITE AND MODULAR CONSTRUCTION TECHNIQUES IN HEALTHCARE BUILDINGS

Brief Background

The use of prefabrication and off-site techniques for healthcare buildings is not new, however, a comprehensive historical analysis is beyond the scope of this paper. Gibb (1999) and Phillips (1996) have provided detailed reviews of the literature on this topic and suggest that, according to archaeological findings, the first use of prefabrication and off-site construction in healthcare buildings dated to the Roman era in the British Isles. The largest of these was the Legionary Fortress at Inchtuthil, Scotland, between AD 83 and 86. Inchtuthil's 170 buildings include a large 600-bed. Other notable designs, based on the concept of prefabrication and off-site construction techniques, were also mentioned in Gibb (1999) and Phillips (1996), as summarised below.

- The hospital design of Isambard Kingdom Brunel, during the Crimea War, included portable hospitals constructed using timber, with the wall panels faced in galvanised sheeting. According to Brunel, *'The construction of each building has been studied with great care, so as to secure the minimum amount of material, the least possible amount of work in construction or erection and the means of arranging all the parts in separate packages, capable each of being carried by two men'* (Brunel in Herbert, 1978; cited in Phillips, 1996; Gibb, 1999, p.11).
- The prefabricated hospitals during the London's smallpox epidemic of 1880 (Taylor, 1991) encapsulated the concept of hospitals as temporary structures allowing rapid response at the onset of an epidemic; a recurrent theme during this period. The hospitals of this era were constructed of prefabricated elements which could be easily erected and then quickly dismantled, hence disinfection was by destruction and removal (Gibb, 1999).
- E.T. Hall's design for the TB sanatoriums at the beginning of the twentieth century comprised a series of 100-bed were based on the concept of standardised, expandable and prefabricated basic sanatorium design (Taylor, 1991).
- Hospital project in the period (1945-1990) was regarded as the backbone of Britain's new National Health Service (NHS). The cut in public expenditure in 1975 prompted change, and a totally new method for hospital planning emerged, hence the creation of small 300-bed hospital tagged 'nucleus' hospital (Anon,1975, cited in Gibb, p.13).

Current Applications of MMC in Healthcare

Although the scope of this paper does not include detailed study of the construction techniques and the materials used in off-site construction, Table 1 summarises the methods currently adopted in general building construction.

Table 1: Types of off-site construction (adapted from Gibb, 1999, 2000)

System Types:	Descriptions:
Non-volumetric pre-assembly	These items generally do not enclose useable space. Examples include parts of the structural frame or cladding of a building, wall panels and pipe work assemblies.
Volumetric pre-assembly	This category referred to units that enclose useable space, however, they do not of themselves constitute the whole building. Examples are toilet pods, plant room units, modular lift shifts etc.
Whole (Modular) building	Modular buildings (commonly referred to as pods) are similar to volumetric pre-assembly, however, the units themselves in this case form the building. Modular buildings may be brought to site with all internal and external finishes, services and in some cases even furnishing.

In general, offsite construction is a MMC which incorporates both prefabrication and preassembly of modules (Gibb, 1999, 2000) usually in a factory whilst ground works and foundations are prepared on site. One important aspect offsite healthcare is modular buildings commonly know as pods. Modular units are delivered to site and craned into position to form the whole or part of the building. Healthcare pods are normally built of steel (or wood) structural frames with in-fill wall panels (e.g. PKL Health, Yorkon and GE Modular). Modular pods are designed with a life span of up to 60 years and can be used for the provision of both permanent and temporary buildings. The pods can be used in conjunction with traditional construction techniques as they are built ready for installation into traditional steel or concrete framed structure of new hospital buildings. Healthcare pods tend to use pre-engineered modular units and are usually installed as fitted-out and serviced building blocks with complex M&E installations. Advance Engineering (PKL Health), employed in offsite fabrication of the modular units, has made possible the construction of large, multi-storey, complex healthcare facilities (e.g. the three-storey ward and theatre facility at Bradford Teaching Hospital, by Yorkon). Modular units can come in various sizes and incorporate a wide range of external finishes including traditional bricks, modern claddings and curtain walling (Gibb, 1999; PKL, 2006; Yorkon, 2006; Terrapin, 2006). Currently, offsite construction techniques provide a wide range of modular buildings for healthcare including: operating theatres, healthcare wards, decontaminating facilities, emergency rooms, diagnostic centres, Doctor's offices for medical, surgical, clinical or dental application, and complete modular healthcare buildings. Table 2 summarises the above.

Table 2: Types of Modular Units

Types of Modular Units:	Description of Structural Frame and Materials:	Sizes: Source :http://www.modspace.com
• Operating theatres • Healthcare wards • Decontaminating facilities • Emergency rooms • Diagnostic centres • Doctor's offices for medical, surgical, clinical or dental application • Complete modular healthcare buildings	• Structural frame are normally of steel. • Internal finishes could be wooden; stucco etc., depending on the client's specification. • External finishes can be of traditional brick appearance, modern cladding materials or curtain walling.	**Designer Series:** Available in a variety of sizes and configurations: • 12ft x 32ft • 12ft x 44ft • 12ft x 56ft • 24ft x 44ft **Prestige Series:** Available in a variety of sizes and configurations: • 12ft x 40ft • 24ft x 40ft • 12ft x 60ft • 24ft x 60ft

HEALTHCARE INFRASTRUCTURE AND THE BENEFITS OF OFFSITE AND MODULAR CONSTRUCTION TECHNIQUES

Various research projects have identified the major benefits of MMC (Gibb, 1999 and 2000; Gibb and Isaac 2003; CIRIA, 2000; National Audit Office, 2005; BRE, 2003, 2004, 2006; Blismas et. al., 2006). Although none of these are healthcare specific, they discuss the general merits claimed by offsite construction. A typical list of these merits include but not limited to: short/reduced build time; better product quality; overall lower cost; better customer satisfaction; adaptability, flexibility; improved health and safety, reduced on-site construction activities and increased sustainability. In the preceding section, however, it was suggested that standardisation, prefabrication (and in fact, offsite and modular construction techniques) have an important role to play in achieving the NHS vision of providing high quality therapeutic healthcare environments; hence, the discussion that follows agues the possible ways the advantages offsite construction techniques can contribute to the attainment of therapeutic environments in healthcare infrastructure. For this purpose advantages of short build time (i.e. fast-track construction), flexibility and better quality of product are used.

Fast-Track construction

Offsite and modular construction techniques compared to traditional methods can save up to 60 per cent of the time required to provide a new healthcare building (PKL Healthcare, 2006). This short construction programme means less construction activities on site, fewer deliveries and less on-site labour. The implication is that issues such as noise due to vibration and dust associated with construction activities are drastically reduced. Reduction of noise is an important factor that aids therapeutic healing environments. A considerable body of evidence has linked noise to the stresses experienced by both patient and staff in the hospital environment (e.g. Hosking and Haggard, 1999; Duffin, 2002). Excess noise in the hospital environment can heighten patient stress, lead to increased amounts of anxiety, pain perception, loss of sleep and prolonged convalescence and increase burnout levels in staff (Cabrera and Lee, 2002; Bayo, *et al.*, 1995). Many findings also suggest that noise is related to some outcomes, for example elevating heart rate (Hilton, 1985; Yinnon *et al.*, 1992).

Hospital acquired infections is another challenging issue in the attainment of a therapeutic healthcare environment. Researchers have identified several studies that linked construction and renovation works within the hospital environment to the source of airborne infection outbreaks due to dust or particulate generation (Humphreys *et al.*, 1991; Iwen *et al.*, 1994; Oren *et al.*, 2001). The studies also identified a source that linked high spore counts of the fungal aspergillosis directly to construction sites in hospital (Opal *et al.*, 1986). Effective prevention or control measures during construction and renovation in healthcare environment include the use of portable HEPA filters, installation of special barriers between patient wards and construction areas. HEPA portable filters have been found to have positive impact on air intakes near hospital construction and renovation sites (Opal *et al.*, 1986; Loo, *et al.*, 1996; Oren, *et al.*, 2001). Reduction of on-site construction activities is also directly related to reduction of dust, offsite construction techniques can thus have positive impact on the reduction of hospital-acquired infections. Also the use of offsite construction methods can dramatically reduce the use of expensive HEPA filters.

Flexibility and Adaptability
Healthcare designers have for long recognised the importance of flexibility in the design and construction of new hospital buildings (James *et al.*, 1986). The current drive for a fundamental change from highly centralised, large hospitals toward smaller, decentralised healthcare buildings (NHS 2006), the very dynamic nature of healthcare methods and information technology, the ever increasing patient expectations for better healthcare delivery (Verderber, *et al.*, 2000) have further reinvigorated the need for flexibility in the design and construction of healthcare facilities (Pilosof, 2005). Offsite construction techniques can be used to accommodate changes of internal space use and changes in clinical services over the building's lifetime (Chefurka and Nesdoly, 2005).

Quality of product
The fabrication of modules (pods) for off-site construction takes place in a factory environment which guarantees a weather-tight and damp-proof fabrication of the modular units. Damp, like dust has also been associated with the fungal aspergillus (Lutz, 2003; McDonald, *et al.*, 1998).

Other aspects of design and construction that can enhance therapeutic environments have include for, example issues such as natural lightning - *Window versus no window* (Ulrich, 2000). The absence of windows in critical and intensive care units have been linked with high rates of anxiety and depression (Keep, *et al.*, 1980; Parker and Hodge, 1976) whereas rooms natural light have been found to foster more positive outcomes (Beauchemin and Hays, 1998). Patient occupancy in the hospital wards is another issue that has been identified as having direct consequences on therapeutic healing -*Multiple beds versus Single bed* (Ulrich, 2000). Studies have shown that the use of single bed is favoured to multiple occupancy especially in intensive or critical (Ognibene, 2000). Using offsite fabrication and modular construction techniques will not only reduce damp that could be trapped into the fabric of the structure during construction, but will also allow precision measurements and proofing during the process of fabrication.

MEASURING THE IMPACTS OF OFFSITE AND MODULAR CONSTRUCTION TECHNIQUES

The Centre for Healthcare Design has developed the Achieving Excellence Toolkit (AEDET). It is a tool specifically designed to assist Trusts and decision-makers to determine and specify their design objectives (NHS-Estate, 2001). It contains three headings: *Functionality, Quality* and *Impact.* The three headings encompass 10 Key design principles. Construction is grouped under the heading "Build Quality" whereas, under the heading *Impact* four principles were enumerated:

- character and innovation;
- form and materials;
- staff and patient environment; and
- urban and social integration.

The benefits associated with modern methods of construction are easy to identify but measuring, quantifying and demonstrating the impact and value associated with such techniques is not so straight forward. The process would involve comparing benefits weighted against each of the above principles enumerated under *Impact* in the

Toolkit's main headings: *Functionality, Quality* and *Impact.* Juxtaposing a construction technique so that it can be evaluated in this way would involve: a complex exercise; a specific project situation with a specific brief; and consultations through workshops or seminars that would involve a multidisciplinary teams of stakeholders (NHS, 2001). Some of the benefits associated with therapeutic impact have been summarised below.

- Using the techniques during the renovation and construction of healthcare facilities could lead to reduction of noise and dust which have direct link with stresses and hospital acquired-infection - *very high positive impact*.
- Using the techniques as the basis for the design and construction of healthcare facilities could provide the flexibility required to take care of the rapidly changing healthcare requirements - *very high positive impact.*
- The fabrication process of the modular units usually takes place in weather-tight environments and the modular units are produced damp-proofed with high engineering precision, this can reduce hospital infections - *very high positive impact.*

CONCLUSIONS

This study has briefly highlighted the needs of the NHS in terms construction specifications. It has also overviewed the use of offsite fabrication and modular construction techniques in healthcare. It is evident from available knowledge that offsite and modular construction techniques are often the *most appropriate construction methods to achieve cost effectiveness, fast and innovative solutions* in the construction of healthcare buildings in the UK. The study also reveals that offsite and modular construction are capable of delivering well-engineered healthcare buildings with good therapeutic qualities.

This paper also discussed the possible impact of offsite and modular techniques on healthcare buildings. Available evidence demonstrates that offsite and modular construction techniques can have positive impacts on healthcare buildings, however, it suggests that the accurate determination of the impact of MMC, specifically offsite and modular construction techniques, in the provision of healthcare infrastructure is a complex process that requires a more robust process to be developed which might include, for example:

- organising seminars, workshops of a multidisciplinary stakeholders in healthcare business including NHS,PFI organisations, architects, modular construction contactors, etc to share knowledge;
- appointing specialist consultants from a broad range of backgrounds to advise on issues such as IT application for modelling and simulation of the various offsite construction processes; and
- holistic assessment of cost and benefits.
- This approach could prove effective since it is based on existing experience which has been used in the housing sector (NAO, 2005).

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