

This item was submitted to Loughborough's Institutional Repository (<https://dspace.lboro.ac.uk/>) by the author and is made available under the following Creative Commons Licence conditions.



CC creative commons
COMMONS DEED

Attribution-NonCommercial-NoDerivs 2.5

You are free:

- to copy, distribute, display, and perform the work

Under the following conditions:

BY: **Attribution.** You must attribute the work in the manner specified by the author or licensor.

Noncommercial. You may not use this work for commercial purposes.

No Derivative Works. You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.

This is a human-readable summary of the [Legal Code \(the full license\)](#).

[Disclaimer](#) 

For the full text of this licence, please go to:
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

REDUCING CONSTRUCTION WASTE IN HEALTHCARE FACILITIES: A PROJECT LIFECYCLE APPROACH

N. Domingo¹, M. Osmani² and A.D.F. Price³

1 N. Domingo, Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK

2 M. Osmani, Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK

3 A.D.F. Price, Department of Civil and Building Engineering, Loughborough University, Leicestershire, LE11 3TU, UK

The NHS has one of the largest property portfolios in the UK, comprising hospitals, clinics, dental offices, out-patient surgery centres, birth centres and nursing homes. Additionally, it is experiencing historic levels of growth with the largest programme of investment the country has ever seen where 25 per cent of hospitals are being replaced or upgraded; 100 new hospitals to be constructed by 2010; and 3000 GP premises being built/replaced/refurbished. As a result, a significant number of environmental concerns and challenges need to be addressed, namely the reduction of water and energy consumption, and more significantly waste generation. In the UK, construction of healthcare facilities creates over 350,000 tonnes of waste, which is about 20 per cent of all generated waste in the UK. Construction waste generation is a global issue and several studies have been performed in different parts of the world to develop methods and tools for waste prevention, reduction, reuse and recycling. However, many of these studies adopted a linear approach by focussing on a specific project phase, such as design, procurement or construction, and a more integrated approach is required to holistically assess and evaluate waste causes and origins throughout the project lifecycle. Hence, this paper, part of a doctoral study, sets out to develop a life cycle construction waste mapping for healthcare facilities. An in-depth literature review has been conducted to identify the extent of the problem and provide a foundation for the PhD study that aims to develop a project lifecycle strategy for reducing construction waste in healthcare facilities. The paper concludes that construction waste is generated throughout the project lifecycle covering design, procurement, construction and demolition. However, literature revealed that there are a number of unique characteristics related to the construction and operation of healthcare facilities if compared with typical buildings, which is mainly due to their organisational and functional complexities. Hence, there is a need to develop a bespoke lifecycle waste mapping in healthcare buildings.

Keywords: [Construction waste, Healthcare, Waste minimisation, Lifecycle]

INTRODUCTION

The construction industry is responsible for producing a whole variety of different waste streams. In USA it contributes approximately 29% of overall landfill volumes, in the UK it contributes more than 50% and in Australia it contributes 20–30% (Rogoff and Williams, 1994; Ferguson et al., 1995; EPA, 1998). The amount and type of construction waste depends on factors such as the stage of construction (Osmani et al., 2008), type of construction work and current supply chain practices (Dainty and

Brook, 2004). As a result, the construction industry is facing enormous pressure to find ways to minimise and manage its waste production. Recently published UK government figures reveals that construction and demolition activities produce 120 million tonnes of waste every year (WRAP,2007a) contributing to more than three times of household waste in UK (DEFAR,2007a). The newly published Waste Strategy for England 2007 (DEFRA,2007b) reveals construction and demolition industry as the major source of waste in England. The National Health Service (NHS) is the largest public sector organisation (Tudor et al.,2005) and one of the largest property portfolios in the UK comprising hospitals, clinics, dental offices, out-patient surgery centres, birth centres and nursing homes (Holmes et al.,2006). It is now experiencing historic levels of growth with the largest programme of investment the country has ever seen in the UK where 25 per cent of hospitals are being replaced or upgraded; 100 new hospitals to be constructed by 2010; and 3000 GP premises being built/replaced/refurbished (SHINE,2006). The increasing number of building projects in NHS generates over 350,000 tonnes of waste during the construction of healthcare facilities which represents about 20% of all UK waste (SHINE,2006); some of which are hazardous, and all of which have the potential to pollute the environment unless properly managed (Townend and Cheesman,2005). Thus, waste arising from healthcare construction in the UK is a pressing concern and urgent actions are required to properly manage and minimise its production.

Past and ongoing research work in the field of construction waste management and minimisation focuses broadly on a number of waste minimisation approaches; such as construction waste reduction through design (Keys et al.,2000; Osmani et al.,2008), construction waste quantification and source evaluation (Faniran and Caban,1998; Ekanayake and Ofori,2000), on-site waste auditing and assessment (Chen et al.,2002) and improvements of on-site waste management practices (McDonald and Smithers,1998). However, many of these studies adopted a linear approach by focussing on a specific project phase, such as design, procurement or construction, and a more integrated approach is required to holistically assess and evaluate waste causes and origins throughout the project lifecycle. This research, part of a doctoral study, has been undertaken to develop a life cycle construction waste mapping for healthcare facilities. Through a comprehensive literature review and analysis, this paper covers: healthcare facilities in UK, sustainable healthcare construction, healthcare waste, sources and origins of construction waste, lifecycle construction waste mapping and the way forward of the forthcoming research.

METHODOLOGY

A comprehensive literature survey and review was conducted to explore the extent of construction waste predicaments in the UK healthcare sector, identify gaps that exist in current stock of literature, and to provide a foundation for a lifecycle approach to minimise construction waste in healthcare facilities.

SUSTAINABLE HEALTHCARE CONSTRUCTION

Healthcare facilities in UK

NHS is the largest business in the Europe (Holmes et al.,2006) and the Learning Network for Sustainable Healthcare Buildings (SHINE,2006) identified the following

key environmental impacts associated with existing facilities and renovation and construction activities in the UK healthcare sector:

- energy consumption approximately 45 million Giga Joules;
- water consumption 40 billion litres per year;
- generates 3.4 million tonnes of CO₂ emissions which is approximately 50% of all UK CO₂ emissions;
- 0.9 million tonnes of carbon emissions;
- 350,000 tonnes of waste (NHS only); and
- construction generates about 20% of all UK waste

The ever-increasing consumption of natural resources and associated environmental impacts created by the healthcare sector in the UK emphasises the importance of sustainable practices in the design, construction, and operation of buildings (SHINE,2006).

Sustainable healthcare construction

Sustainable buildings maximise the benefits that the built assets can bring to the local community and economy whilst minimising the impact of the construction and operation on the environment (SHINE,2006). It brings about the required performance with the least unfavourable environmental impact, while encouraging economic, social, and cultural improvement (ISO,2005). Hence, sustainable construction is the process of delivering healthy built environment based on resource efficient and ecological principles. Additionally, sustainable construction enhances the long-term usability and value of the building, increases productivity of healthcare staff, improves user satisfaction, leads to more productive partnerships with local communities and organisations, and reduces environmental impacts (SHINE,2006).

Specific targets were developed and implemented by the NHS to achieve cost savings and reduce the impact associated with the operation of its existing assets and the construction of new buildings on the environment. These measures were mainly in the areas of operational energy (reduction in primary energy consumption by 15 percent by 2010 based on 2000 levels, and the use of 10 percent of electricity from renewable sources by 2010); water (management of consumption), green transport ;sustainable procurement; and waste minimisation and recycling (NHS Estates,2005).

TYPES OF HEALTHCARE WASTE

Healthcare waste refers to any waste produced by, and as a consequence of healthcare activities (DH, 2006). NHS in England and Wales produces approximately 384,698 tonnes of combined waste per year (Material Health,2004). The complexity of healthcare facilities is the origin of the variety of their disposed waste. The Healthcare Waste Solutions (HWS,2008) has classified the healthcare waste into the following categories: solid waste, hazardous waste, recycled waste, electronic waste(E-Waste), pharmaceutical waste, pathology waste, chemotherapeutic waste and construction and demolition waste.

Healthcare construction waste is defined as any waste that is generated as a result of some form of construction, demolition or renovation that is taking place in a healthcare setting (HWS,2008). Several case studies were undertaken by Waste and Resources Action Programme (WRAP,2006; WRAP,2007b) identified common construction waste material found from healthcare construction projects by monitoring

waste arising during the end of the structural phase, the internal phase and the beginning of the fit out phase of the project. Most common waste materials found from these case studies were plaster board, metal, timber, plastic, concrete, packaging, ceramic, soil, bricks and blocks.

CONSTRUCTION WASTE MINIMISATION

Construction waste source evaluation

It is widely recognised that source reduction is the best way of minimising construction waste and it has been defined as any activity that reduces or eliminates the generation of waste at the source, usually within a process (Begum et al., 2007). Past studies on construction waste source evaluation categorised sources of construction waste in different ways. Pinto(1989), Soibeiman et al.(1994) and Pinto and Agopayan (1994) related construction waste to material types such as steel, cement, concrete, sand, mortar, ceramic block, brick, timber, hydrated lime, wall ceramic tiles and floor ceramic tiles. Gavilan and Bernold (1994) went further to group sources of waste under design, material procurement, materials handling, operation, residual and other. Additionally, Bossink and Brouwers (1996) extended the sources of construction waste further and identified respective causes. Furthermore, Faniran and Caban (1998) identified five typical waste sources: design changes, material scraps, packaging, design errors and poor weather; while Ekanayake and Ofori (2000) categorised construction waste sources under four main categories: design, operational, material handling and procurement.

Major construction waste sources can be related to the design stage, such as design changes, the variability in numbers of drawings, and the inconsistency in the level of design details. Keys et al.(2000) classified origins of design and construction waste under the heading of manufacture, supplier, procurement, designer, logistics, client, contractor and site management. A lifecycle approach to waste source evaluation was introduced by Osmani et al.(2008) and compiled the main causes of waste identified by different authors from inception to completion of a project lifecycle. However, the latter did not consider causes of waste during refurbishment and demolition phases. Although a number of studies reported that waste arises at all stages of the construction process (Gavilan and Bernold,1994; Craven et al.,1994; Faniran and Caban,1998) very little research adopted a lifecycle waste reduction approach.

Lifecycle construction waste mapping

There is a consensus in literature that factors causing construction waste span the project life cycle, including design, procurement, materials delivering and handling, construction and renovation, and demolition. This section summarises the key project lifecycle causes and origins of construction waste that were identified in existing literature (Figure 1).

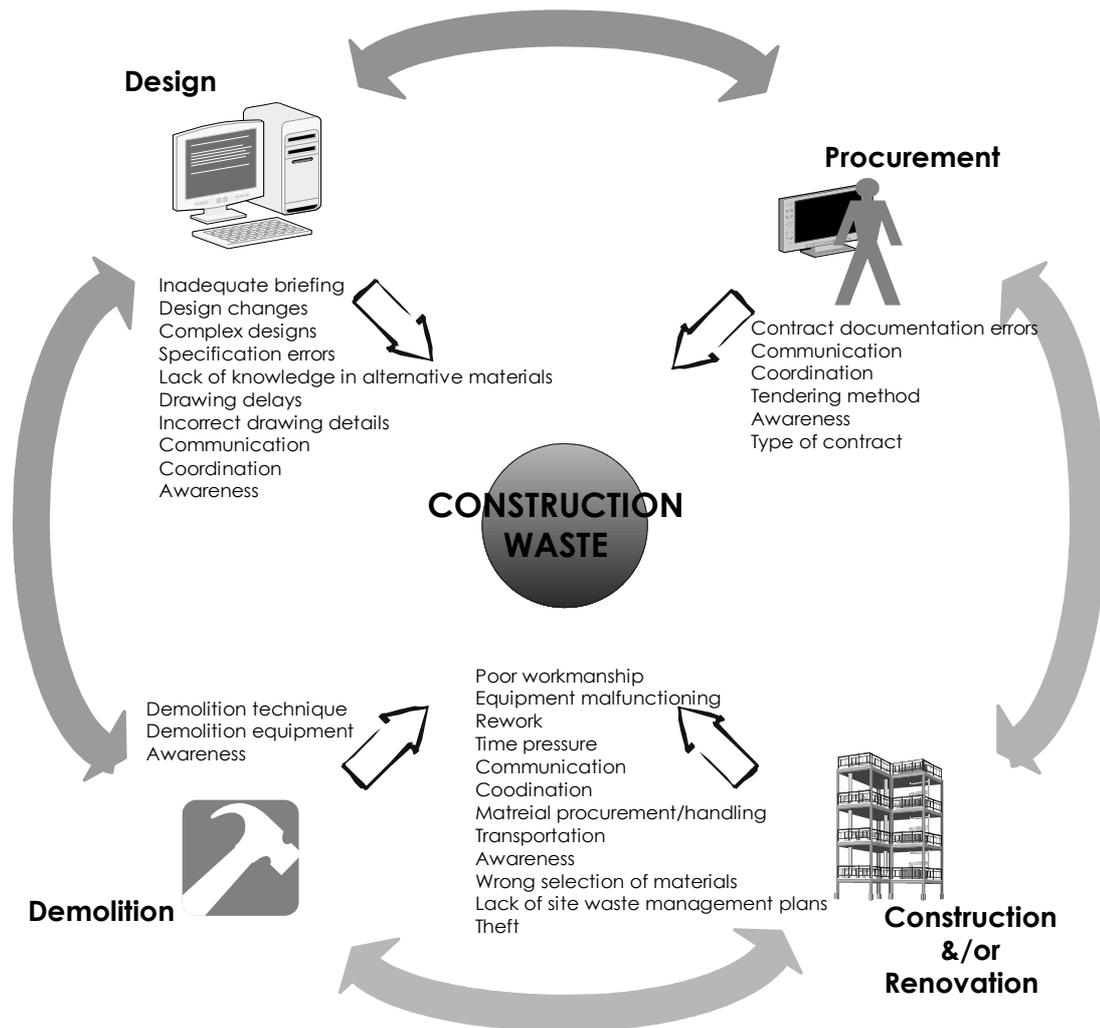


Figure 1: Lifecycle construction waste mapping (compiled from literature)

The design stage accounts directly or indirectly for a considerable amount of onsite waste (Osmani et al.,2008; Poon,2007). As such, Innes (2004) reported that about one-third of construction waste could arise from design decisions. Furthermore, inadequate briefing at the initial stage of the project would lead to design changes and variations during site operations (Osmani et al.,2008; Bossink and Brouwers,1996; Faniran and Caban, 1998). The designer's lack of experience in construction sequence and alternative materials also results in waste generation (Ekanayake and Ofori,2000; Osmani et al.,2008). Additionally, complex designs, over specifications and selection of non-standardised materials create waste (Ekanayake and Ofori,2000; Osmani et al.,2008; Keys et al,2000). Keys et al.(2000) went further to report that a key origin of construction waste generation during the design process is a result of poor communication and coordination among project participants.

Procurement systems have different organisational structures and arrangements that can affect not only the design and construction stages of a project but, also cultural, managerial, environmental and political issues (Masterman,2002). Ekanayake and Ofori (2000) stated that proper selection of a procurement system help in the superior

decision making during the design and construction stages to avoid unnecessary extra work and thus reduce material wastage. As shown in Figure 1, a number of studies (Osmani et al.,2008; Bossink and Brouwers,1996; Ekanayake and Ofori,2000) identified numerous procurement-related waste causes such as type of contract and tendering method.

Construction, renovation and demolition phases in a project lifecycle are stages which create the most significant amount of physical waste. Causes of waste during construction are largely related to labour, equipments and materials used in building activities (Graham and Smithers,1996, Ekanayake and Ofori,2000; Osmani et al.,2008; Bossink and Brouwers,1996) and poor site waste management, transportation, material procurement and handling errors (Keys et al.,2000; Osmani et al.,2008; Ekanayake and Ofori,2000). Even though this study is focusing on the causes and origins of waste in the whole lifecycle of a project demolition waste is obvious. In addressing the impact of demolition waste, Poon et al.(2001) argued that its characteristics vary according to the types of structures demolished and the demolition technique used. Still literature not address the demolition waste issues due to lack of landfill diversion strategies and lack of effectiveness of pre demolition audits.

HEALTHCARE FACILITIES LIFECYCLE WASTE MAPPING

Design

The design of healthcare facilities consists of functional and operationally interconnected built and technical elements that interact with several management systems, which make them complex and rather unique. The complexities over human health implications make design briefing (Lawson,2005), design decisions, material selection and product and equipment specifications quite critical in healthcare buildings compared to other building constructions (Vittori,2002). Effective communication, poor scope definition, unique technical background of stakeholders, complex decision environments are major problems in pre-project phase of healthcare facilities (Lima and Augenbroe,2007). Although these studies identified several pre-project phase inefficiencies that existing healthcare facility construction, to date there is no significant research on the causes and origins of construction waste related to all stages of healthcare construction projects.

Procurement

Most of healthcare building projects in the UK are funded through the private finance initiative (PFI) mechanism (Lawson,2005). This is a system where by the private sector undertakes to finance the total procurement process on behalf of the public sector and payment being delayed until the project is completed and ready for occupation at handover (Bagnal et al.,1999). Since most of healthcare buildings use PFI procurement system, the waste generation in design, construction and maintenance phases are heavily dependent on causes of waste related to PFI procurement system. Gamage et al.(2007) argued that there is a small but growing body of literature that attempt to explore the effects of procurement methods on construction waste generation and minimisation. Similarly, McDonald and Smithers (1998) suggested that the future work should involve assessing the ways in which different procurement systems affect the generation of waste as a result of different interrelationships within the project participants due to alternative uses of procurement systems. Gamage et al.(2007) went further to acknowledge the need of mapping the

causes and origins of waste under each procurement system. Several case studies such as, Derby City General Hospital, Great Western Hospital, Barts and The London Hospital, St. Bartholomew's and the Royal London Hospital which were recently completed by WRAP revealed that large portion of construction waste reduced and high rate of recycling achieved through PFI procurement system. In most of the above mentioned case studies it is estimated that around 25%-30% of material can recycle at no extra cost while, Constructing Excellence (2003) achieved 50% waste reduction through designing out waste and recycling. Hence, identification of the widely used procurement systems in construction of healthcare facilities other than PFIs and customising the causes of waste specific to the healthcare procurement systems will help developing efficient waste minimisation approaches in the construction of healthcare facilities.

Construction/ Renovation

Most of the causes for waste in construction phase listed in Figure 1 are common to all construction projects irrespective of the nature and size of the construction. Healthcare constructions are very large projects involving huge investments and thus proper onsite waste management techniques are required to obtain the best value for investment. In UK, most of the major healthcare contractors such as Yorkon, Skanska and Laing O'Rourke use off site construction in order to reduce on site waste and expedite the construction process, which were successfully implemented in a range of projects such as Watford General Hospital, Walsall Manor Hospital, and Portsmouth St Mary's NHS Treatment Centre. This would suggest that offsite prefabrication could have a significant impact on onsite waste reduction. However, literature reveals that little has been done to identify the sources and origins of offsite construction waste. Additionally, the healthcare sector witnesses a high rate of change during the operation phase, as interior spaces are reconfigured, remodelled and outfitted with new furnishings and equipment reflecting changes in management and delivery systems (Vittori,2002) which ultimately contribute to waste creation.

Demolition

Demolition waste is responsible for generating the highest proportion of waste in a project's lifecycle and it was revealed that approximately 92% of all construction and demolition waste are from modification and demolition (Environmental Protection Agency,1998). In the case study of Barts and the London Hospital (WRAP,2007b), which is the largest PFI healthcare scheme ever to be signed in the UK, over 97% of onsite demolition waste was reused and recycled. This would suggest that proper onsite waste management plans can effectively reduce the total waste generation from healthcare building demolition.

CONCLUSION

This paper explores the construction waste paradigm within the healthcare construction industry in the UK and established the foundation for a doctoral research to develop a lifecycle approach to minimise construction waste for healthcare facilities. Literature revealed that there is an undergoing growth in healthcare facility built assets in UK, which gave rise to significant environmental concerns, namely construction waste generation, which is expected to increase due to the extensive healthcare construction development. The extant of literature revealed that construction waste is generated throughout the project lifecycle covering design,

procurement, construction and demolition. More importantly, literature failed to identify recent or ongoing research work to pinpoint waste causes and origins specifically related to the design, procurement and construction of healthcare buildings. Furthermore, there are a number of unique characteristics related to the construction and operation of healthcare facilities if compared with typical buildings, which is mainly due to their organisational and functional complexities. Hence, there is a need to develop a bespoke lifecycle waste mapping in healthcare buildings. The next stage of this research will focus on preliminary quantitative and qualitative data collection with the key healthcare construction stakeholders to identify causes and origins of waste. This would feed in the subsequent methodology stages that will lead to the development of a lifecycle waste minimisation framework for the healthcare sector.

REFERENCES

- Bagnal et al.,1999. Tenders and Contracts for building. 3rd edition. Blackwell Science Ltd., United Kingdom.
- Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H.,2007. Implementation of waste management and minimisation in the construction industry of Malaysia. *Resources Conservation and Recycling*, 51, 190-202.
- Bossink, B.A.G., and Brouwers, H.J.H.,1996. Construction waste: Quantification and source evaluation. *Journal of Construction Engineering and Management*, ASCE, 122(1), 55-60.
- Chen, Z., Li, H., and Wong, C.T.C.,2002. An application of bar-code system for reducing construction wastes. *Automation in Construction*, 11(5), 521–533.
- Constructing Excellence,2003. Whole life analysis for new hospital. Available at: http://www.constructingexcellence.org.uk/download.jsp?url=/pdf/case_studies/CB191.pdf, (Accessed on: 15 April, 2008).
- Craven, D.J., Okraglik, H.M. and Eilenberg, M.,1994. Construction waste and a new design methodology. *Sustainable Construction: Proceedings of the 1st Conference of CIB TG16*, Tampa, FL, November 6-9, 89-98.
- Dainty, A.R.J. and Brooke, R.J.,2004. Towards improved construction waste minimisation: a need for improved supply chain integration. *Structural Survey*, 22, 20-29.
- DEFRA- Department of Environment, Food and Rural Affairs,2007a. Construction On Site Waste management Plan For the Construction Industry. Department of Environment, Food and Rural Affairs, London.
- DEFRA- Department of Environment, Food and Rural Affairs,2007b. Waste Strategy for England 2007. TSO (The Stationery Office), UK.
- DH,2006. Environment and sustainability Health Technical Memorandum 07-01: Safe management of healthcare waste. Department of Health, UK.
- Ekanayake, L.L., and Ofori, G.,2000. Construction material waste source evaluation. In: *Proceedings of the Second Southern African Conference on Sustainable Development in the Built Environment: Strategies for a Sustainable Built Environment*, Pretoria, 23–25 August.
- Environmental Protection Agency,1998. Characterization of Building Related Construction and Demolition Debris in the United States. EPA 530-R-98-010.

- EPA,1998. Construction and Demolition Waste Action Plan. Environment Protection Authority, NSW, Australia.
- Faniran, O.O. and Caban, G.,1998. Minimizing waste on construction project sites. *Engineering Construction and Architectural Management*, 5(2), 182–188.
- Ferguson, J., Kermod, N., Nash, C.L., Sketch, W.A.J. and Huxford, R. P.,1995. *Managing and Minimising Construction Waste: A Practical Guide*. Institution of Civil Engineers, London.
- Gamage, I.S.W., Osmani, M. and Glass, J., 2007. Assessing the relationship between procurement systems and waste generation in construction. *Proceedings of The Third Scottish Conference for Post Graduate Researchers of the Built and Natural Environment - PRoBE*, Glasgow, November, 149-157.
- Gavilan, R.M. and Bernold, L.E.,1994. Source evaluation of solid waste in building construction. *Journal of Construction Engineering and Management*, 120(3), 536-552.
- Graham, P.M. and Smithers, G.,1996. Construction waste minimisation for Australian Residential Development. *Asia Pacific Building and Construction Management Journal*, 2, 14–19.
- HWS,2008. Waste Streams. Healthcare Waste Solutions. Available at: <http://www.hwsusa.com/2minute.asp>, (Accessed on: 19 March, 2008).
- Holmes, J., Capper, C. and Hudson, G.,2006. LIFT: 21st century health care centres in the United Kingdom. *Journal of Facilities Management*, 4, 99-109.
- Innes S.,2004. Developing tools for designing out waste pre-site and on-site. *Proceedings of Minimising Construction Waste Conference: Developing Resource Efficiency and Waste Minimisation in Design and Construction*, New Civil Engineer, London.
- ISO,2005. Building construction – sustainability in building construction – sustainability indicators, Part 1 – Framework for the development of indicators for buildings, ISO TS 21929, New York.
- Keys, A., Baldwin, A., and Austin, S.,2000. Designing to encourage waste minimisation in the construction industry. In: *Proceedings of CIBSE National Conference*, September, Dublin, Republic of Ireland.
- Laing O Rourke, Healthcare. Available at: http://www.laingorourke.com/sectors_healthcare.htm, (Accessed on: March 2, 2008).
- Lawson, B.,2005. Evidence based design for healthcare. *Business Briefing: Hospital Engineering and Facilities Management*, 2, 25-27.
- Lima, C. and Augenbroe, G.,2007. The Use of Formal Methods for Decision Making in the Planning Phase of Healthcare Facilities, COBRA, RICS.
- Masterman, J.W.E.,2002. *Introduction to Building Procurement Systems*. 2nd Edition, Spon Press, London.
- Material Health,2004. *A Mass Balance and Ecological Footprint Analysis of the NHS in England and Wales*. Best Foot Forward Ltd, Oxford, UK.
- McDonald, B., and Smithers, M.,1998. Implementing a waste management plan during the construction phase of a project. *Journal of Construction Management and Economics*, 16(1), 71–78.
- NHS Estates,2005. *Sustainable development: Environmental strategy for the National Health Service*. HMSO, London, UK.
- Osmani, M., Glass, J. and Price, A.D.,2008. Architects perspectives on construction waste minimisation by design, *Waste Management*, 28(7), May 2008, 1147-1158.

- Pinto, T.P.,1989. Perda de materiais em processos construtivos tradicionais. UFSCAR Departamento de Engenharia Civil, Sao Carlos, Brazil.
- Pinto, T.P., and Agopayan, V.,1994. Construction waste as raw materials for low cost construction products. Sustainable construction, Proceedings of The first Conference of CIB TG 16, Gainesville, Florida, 335-342.
- Poon, C.S., Yu, A.T.W. and Ng, L.H.,2001. On-site sorting of construction and demolition waste in Hong Kong. Resources Conservation and Recycling, 32, 157-172.
- Poon, C.S.,2007. Reducing construction waste. Waste Management, 27, 1715-1716.
- Rogoff, M.J. and Williams, J.F.,1994. Approaches to Implementing Solid Waste Recycling Facilities. Noyes, Park Ridge, NJ.
- SHINE,2006. SHINE Learning Network for Sustainable Healthcare Buildings. Available at: www.shine-network.org.uk, (Accessed on: 18 March, 2008).
- Skanska, Medical centre. Available at: <http://www.skanska.co.uk>, (Accessed on: 2 March, 2008).
- Soibelman, L., Formosa, C.T., and Franchi, C.C.,1994. A study on the waste of materials in the building industry in Brazil. Sustainable construction, Proceedings of The first Conference of CIB TG 16, Gainesville, Florida, 555-563.
- Townend, W.K. and Cheesman, C.R.,2005. Guidelines for the evaluation and assessment of the sustainable use of resources and of wastes management at healthcare facilities. Waste Management and Research, 23, 398-408.
- Tudor, T.L., Marsh, C.L., Butler, S., Vanhorn, J.A. and Jenkin, L.E.T.,2005. Realising resource efficiency in the management of healthcare waste from the Cornwall National Health Service (NHS) in the UK. Waste Management, In Press, Corrected Proof.
- Vittori, G.,2002. Green and Healthy Buildings for the Healthcare Industry. Center for Maximum Potential Building Systems, Austin, Texas.
- WRAP,2006. Waste Recovery Quick Win Case Studies. Available at: http://www.wrap.org.uk/construction/construction_waste_minimisation_and_management/wrqw_case_studies.html, (Accessed on: 21 March, 2008).
- WRAP,2007a. Halving construction waste to landfill by 2012. Available at: http://www.wrap.org.uk/downloads/Halving_waste_to_landfill_briefing_note.803d673.pdf, (Accessed on: 15 April, 2008).
- WRAP,2007b. Recycling demolition arisings at Barts and The London Hospital. Available at: http://www.wrap.org.uk/downloads/Barts_and_The_London_Report_full_case_study.989cb269.pdf, (Accessed on: 21 March, 2008).
- Yorkon, Healthcare Case Studies. Available at: <http://www.yorkon.co.uk/healthcare.dc>, (Accessed on: 21 March, 2008).