Evaluating the Functional Performance of Small-Scale Public Demountable Buildings

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy by:

Junjie Xi

June, 2013

Abstract

This thesis investigates the design, operation and use of contemporary demountable buildings, and explores how functional performance can be assessed in small-scale examples for public use alongside with their relationship to other design elements. The research focuses on three case studies that do not require a high-technology building environment or complex construction skills. Demountable buildings are defined as those that are transported in a number of parts for assembly on site. Contemporary demountable buildings respond to ecological issues, social impacts, technological innovation and economic demands. They can be used to measure a society's development in environmental sustainability, innovation and economic growth through various forms. Small-scale demountable buildings fulfil many temporary habitation needs in diverse roles, such as non-emergency transitional housing, ephemeral exhibition buildings and seasonal entertainment facilities.

The purpose of examining functional performance is to assess if, and how, the requirements of the design have been achieved. This enables project operators to address functional performance from a public perspective by reflecting on the scope and ambition of their projects. This thesis draws on existing literature to investigate previous and on-going research relating to demountable buildings, including classification, the construction process and project management. It also examines selected existing evaluation methods that cover principles, modelling and computer-based solutions from a wider research area, including Guidelines Developed by City Council and Culture Sectors; Assessment Methods in Humanitarian Response and Methods in Environmental Assessment.

The research was conducted by combining both quantitative and qualitative research methods, including field research, case studies, interviews, questionnaires and group discussions. Fragmented narratives were transformed into structured evidence, identifying models of best performance in demountable buildings and developing a new method – the Evaluation Conceptual Model – for the effective evaluation and evidencing of the value of demountable buildings in the 21st century. Recommendations for adapting a suitable model to evaluate other design elements in demountable buildings and other types of moveable buildings in further research are suggested and the findings have been used to lay the foundations for a practical evaluation tool for the future.

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Acknowledgements

I would first like to thank the School of Architecture, University of Liverpool, for their continued support over the past three years. I would also like to express my sincere thanks to the University of Liverpool Graduate Association (Hong Kong). The Association has financially enabled me to test parts of this research in conference presentations, and to finalise the results in a number of publications. In particular, I would like to thank my supervisors, Professor Robert Kronenburg, for his invaluable guidance and substantial support, and Mr John Lewis, for his insightful advice and positivity. I am extremely grateful for their close supervision. I would also like to thank Dr Carolina Stevenson for her valuable advice on the typology of kinetic structures, Dr Halim Boussabaine for his good advice on design quality indicators, and Mr Moshabab Aljarman for his information on the Mina Tents Valley in Mecca.

My sincere gratitude goes to Professor André Brown and Professor Barry Gibbs, for their positive support and friendly advice. Thanks also go to Marion, Craig and Chris at the School of Architecture, University of Liverpool, for their kind help. My thanks also go to my former supervisor, David Bromilow at the University of Leeds, who guided and encouraged me on this academic path when I studied at the Design School from 2008 to 2009.

I would like to say thank you to Yasunori Harano, Reiji Watabe, Lin Hou, Hong Yin, Jing Deng, Xiaodu Liu, Alan Parkinson, Mado Ehrenborg and Chunqing Li for their kindness and generosity in providing solid information and long-term cooperation for the case studies.

A special thank you goes to Jane Clayton, Nick Webb and Mike Otchie, who have accompanied me on this wonderful journey. I would also like to thank Ataa, Antoinette, Shama, Judith, Haniyeh, Anna, Mai, Yemi, Yusuf, Elaheh, Duygu, Sureepan and Ruxandra for their friendship and support.

A very special thank you goes to my parents and grandma, for their love, patience, understanding and support.

Preface

My interest in moveable architecture started when I studied at the Design School, University of Leeds. My graduation project was to design a small space for temporary museum exhibitions. During the design process, I was particularly concerned with access for people with disabilities who are often unable to experience museum exhibitions in the same way as other visitors. One of the limitations of traditional museum exhibitions is that the objects cannot easily be relocated, and my field of research focused on the more interesting and challenging moveable objects. I was fortunate to meet Ceinwen Paynton the Principal Keeper at Leeds City Museum, who introduced me to Caroline McDonald, Curator of Archaeology at Colchester Museum, and Gabrielle Hamilton, Curator of Community History and Antonia Lovelace, Curator of Anthropology, from Leeds Museum Discovery Centre. I discovered the idea of a 'museum in a suitcase', where curators fill a vintage suitcase with museum objects and take them on journeys to outdoor events. I began to re-think my current design and completed a portable museum design project. The final design was a house-shaped structure that displays museum objects in many protected boxes hung from trees in different parks during both daytime and early evening.

The diversity of moveable architecture and its extremely high value for social, environmental and economic debates encouraged me to further explore the use of portable and adaptive architecture, which has become increasingly important to the growth and development of cities globally, due to limited land and resources, and to increasing population levels posing challenges to the built environment. I found that there was no evaluation system that could be directly applied to moveable architecture for its sustainable development. In order to further my research interests, develop more sophisticated research methods and, eventually, have an important impact on this field, I joined the School of Architecture, University of Liverpool on 1 October 2009. By reviewing the contemporary literature, I specifically focused on small-scale public demountable buildings after comparing them with portable buildings and relocatable buildings. The main challenge was to identify the key features of small-scale, public-use demountable buildings and to develop the factors into a series of evaluation indicators. The methodology was to thoroughly explore the design, operation and technology of contemporary demountable buildings and this procedure enabled me to obtain an extensive understanding of this type of architecture.

1

Introduction

Travel and change of place impart new vigor to the mind.

– Lucius Annaeus Seneca[1]

1.1 Introduction

The term *demountable building* encompasses a wide range of constructions that have a shared attribute: the ability to be deployed and transported from site to site for re-use or recycling. Many other terms, such as *moveable*, *mobile*, *portable*, *foldable*, *deployable*, *transformable*, *relocatable*, *adaptable*, *kinetic* and *adaptive*, are often used to describe similar designs. Although these terms share a similar meaning, they can be interpreted differently depending on the specific circumstances. This thesis will focus on demountable buildings because:

(i) They have been widely used around the world and are becoming increasingly important. There is a growing need for empirical research related to this area for many reasons, including the application in areas of high population and urbanisation.

(ii) They are distinct from static buildings in the process of dismantling, a process which is, therefore, central to the analysis of this particular type of building. Unlike demolition, dismantling enables valuable construction materials to be salvaged. The hypothesis here is that the evaluation of demountable buildings

[1] Lucius Annaeus Seneca, (4 BC - AD 65).

can be considered by observing and analysing the dismantling process. This process can be divided into two main aspects: environmental performance; and functional performance. However, in this case, the focus remains on functional performance.

(iii) The majority of contemporary demountable buildings have been located in open public spaces with easy access. A well-presented demountable building does not only save construction time and costs, but can also help to provide economic benefits, such as raising public awareness and advertising exhibited projects.

Small-scale projects are flexible in function and adaptable in structure. They are the most commonly used type of contemporary moveable architecture. They require low budgets, small working teams and small building sites and, most importantly, the ability to be assembled and dismantled in a relatively short period of time. Small-scale projects can encourage design innovation and can be useful for design experiments. Analysing such small-scale projects can help to improve the understanding of the design of all buildings.

Focus is on public buildings for two main reasons: universality because the majority of contemporary demountable buildings are for public use, despite evidence of a range of demountable residential shelters and temporary houses; and diversity, because public-use demountable buildings fulfil many temporary needs, such as non-emergency transitional schools, ephemeral exhibitions and seasonal entertainment.

The purpose of examining functional performance is to assess if, and how, the requirements of the design have been achieved. The value of this research is, therefore, in the establishment of a set of relevant criteria as a systematic evaluation option, enabling project operators to begin to address functional performance from a public perspective and reflect on the scope of their projects. This relies upon the assumption that a specific evaluation method for public demountable buildings can be adapted to other types and scales of demountable buildings in future research. The possible approaches for how the research results can fit within the broader area are recommended in the concluding chapter.

This chapter provides a sense of the content and context of this thesis by highlighting the key issues to be examined in the research. The chapter also defines the research problems and perspectives, presenting the research hypothesis, aim, objectives and study subject before outlining the structure of the thesis is described.

1.2 Prehistoric Background and Traditional Shelters

The use of demountable buildings began in ancient times, evidence for which can been seen around the world, including in the partly subterranean houses of cane and grass, with whale rib bones for internal support, located in the Chilca valley of central Peru (Figure 1.1.). The site was known to be occupied around 5,400 years ago, and early farmers living there grew beans and gourds, and collected many wild plants, shellfish and fish. Other ancient forms of early shelter include tipis, tents, yurts and igloos. For example, the classic dwelling of Siberian and Mongolian nomadic herders provides the minimum of exposed surfaces and maximum stability to adapt to the migratory lifestyle as people move seasonally for food and for their animals to forage.[2] Evidence can also been seen in the snow houses, or igloos, developed for the tundra of the Arctic and used by the Inuit as winter homes or temporary bases for hunting parties.[3]

Jonathan Horning states that the primary and oldest function of shelters is to provide of protection against weather, extreme temperatures and foes. Secondary functions are the provision of comfort, aesthetics and privacy.[4] Shelters were also broadly used for military purposes, and as recorded in *The Art of War* – the ancient Chinese military treatise attributed to Sun Tzu, who lived between 544 BC and 496 BC – a type of machine called Fen Wen (Figure 1.2.), made from wood and covered with animal skin, was used to carry ten people from one location to another. It was used by soldiers who were protected from stones and other weapons by the house-shaped structure.

[2] Marilyn Walker, "Circumpolar Shelter," In Andreas Muller, *Arctic Perspective Cahier No. 1* (Hatje Cantz Verlag GmbH & Co KG, 2011), 75.
[3] Jonathan Horning and Brock Horning, *Simple Shelters : Tents, Tipis, Yurts, Domes and other Ancient Homes* (New York: Walker & Co., 2009), 46.
[4] Ibid., 2.

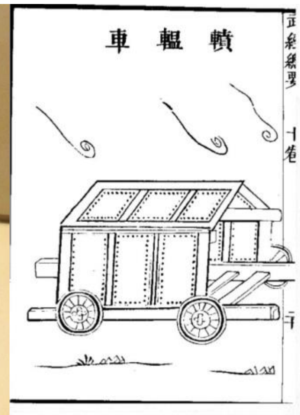

FIGURE 1. 1. - FIGURE 1. 2. Ancient shelter in Peru;[5] Fen Wen[6]

Horning states that all ancient shelters, whether nomadic, seasonal or settled,[7] evolved as functional responses to the local climate, the availability of materials and temporal requirements. He believes that the form of ancient shelters is related to the relevant geological and climate conditions, his general classification is presented in the following table:

TABLE 1.1. Shelter form comparison[8]

Shelter Form	**Geographical Location**	**Weather**	**Material**
Tipi	North America	Plains, dry prairie	Fabrics, animal skin, wood
Conical hut	Generic Africa	Tropical and temperate zones	Mud, clay, sod, stones, straw
Igloo	Northern	Ice belt, tundra	Snow blocks, animal skin
Black tent	Dry desert, Iran, Tibet, North Africa, Arabia, Iraq, Syria	Hot, dry	Wood, fabrics, animal skin
Yurt	Asia (Turkey, Mongolia, Kazakhstan, Kyrgyzstan)	Semi-arid steppes	Wood, timber, fabrics, animal skin
Bamboo hut	Tropical, rainforest	Hot, humid	Bamboo, straw
Yaranga	Asia, Sub-Arctic	Cold, humid	Wooden frame, reindeer skin, canvas

Despite their simple appearance, the shelters are not simplistic and they attract researchers wishing to study their natural form from various perspectives. A comprehensive categorisation of simple shelters is proposed by René K. Müller, who makes and inhabits traditional temporary shelters. Based on practical experience and theoretical knowledge, Müller distinguishes simple shelters as tipis, yurts and domes.

[5] This model is in the American Museum of Natural History in New York, United States.
[6] "Gong Cheng Shu," ed. Fen Wen.
[7] Horning and Horning, *Simple Shelters : Tents, Tipis, Yurts, Domes and other Ancient Homes*: 1.
[8] Ibid.

He further identifies the dome typology as having five types: geodesic dome, bow dome, zome, star dome and wigwam.[9] Interestingly, Müller assesses each structure type and ranks them based on four criteria: simplicity, portability, comfort and size flexibility (Table 1.2.).[10]

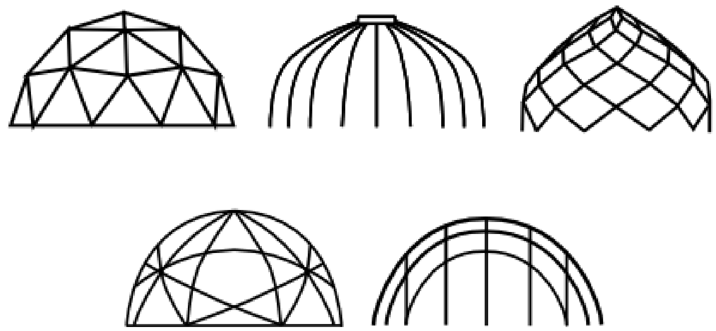

FIGURE 1. 3. - FIGURE 1. 7. Geodesic dome; Bow dome; Zome; Star dome; Wigwam[11]

TABLE 1.2. Simple shelter comparison proposed by René K. Müller[12]

	Simple Shelter Comparison																					
		Simplicity					**Portability**					**Comfort**					**Size flexibility**					**Overall**
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Tipi																						3
Yurt																						3.5
Dome	Geodesic dome																					2.75
	Bow dome																					3
	Zome																					3
	Star dome																					2.75
	Wigwam																					3

Based on Müller's assessment, the yurt is ranked as having the highest score among the different types of shelter, which indicates best performance in construction and function. The result also suggests that the wooden-framed yurt is the most portable structure, although it has an average flexible size and requires complex construction skills. Robert Kronenburg categorises simple shelters into: tents, as utilising tensile fabric engineering with minimal and relatively heavy-compression elements; tipis as single cells made of a space frame, and incorporating a twin-skin environmental wall for

[9] René K. Müller, "Simply Differently," http://simplydifferently.org/ (accessed 12 January 2013).
[10] Ibid.
[11] ———, "Selected Shelters," (2012).
[12] ———, "Simply Differently".

ventilation and insulation; and yurts as manufactured using modular systems incorporating a geodetic wall structure.[13]

In addition to dwellings that were built on land, there is a long history of floating housing, such as the Huafang, a well-known boat-house type in China. This translates from Mandarin as "well decorated boat", with the earliest recorded picture of a Huafang being in a painting, *Nymph of the Luo River* (Figure 1.8.), by celebrated ancient Chinese painter Gu Kaizhi, who lived from AD 344 to AD 406 (Jin Dynasty).[14] The Huafang was developed further in both function and appearance during the Tang Dynasty (AD 618–907), Ming Dynasty (AD 1368–1644) and Qing Dynasty (AD 1644–1912). In ancient China, China wood oil (tung oil) was used as a drying oil to protect wooden boats from water. Tung oil is obtained by pressing the seed from the nut of the tung tree. Clearly inspired by ancient Chinese timber architecture, the design of the Huafang provided a comfortable and luxurious place for outdoor entertainment, including singing, dancing and plays. The performance stage could be relocated as a whole onto a boat to provide people with an opportunity to enjoy plays inside a "house" with a natural moving background (Figure 1.9.).

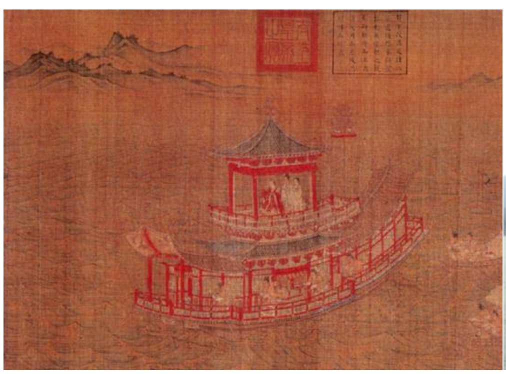


FIGURE 1. 8. - FIGURE 1. 9. Section of the *Nymph of the Luo River;*[15] Huafang in the West Lake, Hangzhou, China

A key characteristic of ancient shelters is the fact that they were man-made with simple tools and, therefore, the aesthetics relied heavily on the craftsman's skills. They were constructed from natural materials and, because of limited resources, some were treated with simple natural materials. Although these traditional building types require

[13] Robert Kronenburg, *Houses in Motion* (London: Academy Editions, 2002), 18-23.
[14] The story of this painting is based on a long poem written by Prince Caozhi (AD 192–232), which tells the romantic tale of Caozhi's meeting with the Nymph of the Luo River (Luoshen), a daughter of the mythical ruler Fuxi.
[15] Gu Kaizhi, "Section of the Nymph of the Luo River," (AD 344-406).

relatively low technology skills, their design systems have, for generations, inspired architects and engineers towards more sophisticated designs and construction techniques. Even today, architectural historians and researchers are still fascinated by the form, function and history of these ancient and traditional building types, and there is no doubt that their value continues to support and motivate contemporary architects and designers in developing more advanced building designs.

1.3 Prefabrication, Invention and Lightweight Constructions

The 19th century period of industrialisation offered prefabrication and transportation, and had a revolutionary impact on demountable buildings. Arnt Cobbers, Oliver Jahn and Peter Gössel write: "The use of mass-produced nails, rather than expensive hand-wrought nails, made it possible to construct a house solely out of boards that any sawmill could deliver by using nailed joints. Mortise and tenon joints, as used in timber frame houses, were no longer necessary."[16] The emergence and spread of prefabrication is closely related to the life of pioneers in early days, and the first manufacturer to address the more general issue of the mass-market demountable building was John Manning, a London carpenter and builder who, in around 1833, conceived the Manning Portable Colonial Cottage.[17] This structure was designed to utilise a small volume for effective use of shipping space, to be easy to erect and, as repetitive parts were of the same dimensions, to be modular.[18] Cobbers, Jahn and Gössel argue that long before the word *prefabrication* existed, Manning had developed a system that worked by precisely adhering to standard measurements, with panels, posts, and plates that each had the same length, breadth and thickness and, therefore, could be easily installed. As such, Manning created the prototype of the modern prefabricated house.[19]

Prefabrication is "a child of nineteenth-century industrialisation"[20] and the Crystal Palace, which was exhibited in London in 1851, is an outstanding example of the new industrial mindset in building culture, as well as of the innovative organisation of

[16] Arnt Cobbers, Oliver Jahn, and Peter Gössel, *Prefab Houses* (Köln: Taschen, 2010), 9.
[17] Ibid., 30.
[18] Kronenburg, *Houses in Motion*: 44.
[19] Cobbers, Jahn, and Gössel, *Prefab Houses*: 30.
[20] Ibid., 9.

planning, building sites and building processes.[21] Ulrich Pfammatter assesses the contribution of the Crystal Palace by stating that:

> It demonstrated how constructing enormous volumes with the tightest of budgets and time restrictions and the greatest of precise detail could be achieved rationally and with an industrial mindset, and reveals an understanding of a building as a multi-layered overall system and the building process as a multi-disciplinary problem, which was new at the time and anticipated the future of modern construction.[22]

In the 20th century, many architects, designers, engineers and inventors showed a particular interest in designing and manufacturing demountable and moveable housing. For example, the Dymaxion Deployment Unit (DDU) – developed by Richard Buckminster Fuller in collaboration with the Butler Manufacturing company in Kansas City in 1940 – was a project commissioned by the United States government. The DDU, in which the external wall and the supporting structure formed a single unit, could be easily erected and dismantled. There are many other historical examples, such as Maison Tropicale, designed by Ateliers Jeans Prouvé from 1949 to 1951 in Maxéville, France; Futuro, a UFO-like house designed by Finnish architect Matti Suuronen in 1965; and Bulle Six Coques, designed by French architect and city planner Jean Maneval in around 1967.

Alongside the development of industrial inventions, research and practice in lightweight construction also flourished during the same time period. According to Winfried Nerdinger and Rainer Barthel, Frei Otto's work in lightweight and adaptable constructions first caused a stir in 1954 with his doctoral thesis *Suspended Roofs*,[23] and he has continued to produce important stimuli and innovative ideas since.[24] Otto was determined to reject any form of heavy, solid, earthbound building, and his German Pavilion at Expo 67 in Montreal brought "international recognition for the transformation into a new, peaceful democracy".[25] His demountable umbrella design was widely used and appreciated around the world, including Europe and the Middle East. Together with Bodo Rasch, Otto's inventions were remarkably successful in Saudi

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[21] Ulrich Pfammatter, *Building the Future : Building Technology and Cultural History from the Industrial Revolution until Today* (Munich; New York: Prestel, 2008), 74.
[22] Ibid.
[23] A suspended roof means a membrane stretched between fixed points that forms a roof structure and roof covering at the same time. Frei Otto's thesis *Suspended Roof* was given a grade of "good"; it was published by the Bauwelt Publishing House in Berlin in 1954 and soon had a large influence on architectural practice.
[24] Frei Otto, Winfried Nerdinger, and Architekturmuseum Technische Universität München, *Frei Otto : Complete Works : Lightweight Construction, Natural Design* (Basel; Boston: Birkhäuser, 2005), 6.
[25] Winfried Nerdinger, "Frei Otto Working for A Better Earth for Mankind,"ibid., 11.

Arabia and the Gulf region, for example, the adaptable umbrella in the inner courtyard of the Mosque of the Prophet, Medina, which was designed and constructed in 1992, and provides shade for pilgrims through the use of common materials and aesthetically pleasing surfaces.

Together with lighter forms of construction in steel, glass, fabrics and plastics, the "tensegrity" experiments in 1948 established a new era with regards to space, load-bearing structures and the technology emerging in architects' and engineers' fields of design. The "tensegrity" structural principle was discovered by Kenneth Snelson and Buckminster Fuller, and in, "The Art of Tensegrity", Snelson states that:

> In 1996, Vliyme 11 Nos. 1 & 2 of this Journal, the different views of Buckminster Fuller, David George Emmerich and Kenneth Snelson were thoroughly debated. I told of Mr Fuller's 1959 New York Museum of Modern Art exhibition when he finally credited me for discovering the tensegrity principle.[26]

FIGURE 1. 10. - FIGURE 1. 11. WoodX-Column 1948;[27] "Easy landing" on the Inner Harbor of Baltimore, Maryland[28]

"Tensegrity", by combining the words *tensile* and *integrity* means integral tensile stress.[29] Donald E. Ingber defines it as an architectural system in which structures stabilise themselves by balancing the counteracting forces of compression and tension, and compares cell composition to both Snelson's sculptures and Buckminster Fuller's geodesic domes.[30] Chris Wilkinson, of Wilkinson Eyre Architects Company, lists the

[26] Kenneth Snelson, "The Art of Tensegrity," *International Journal of Space Structures International Journal of Space Structures* 27, no. 2 (2012): 71.
[27] ———, "WoodX-Column1948," (1948).
[28] ———, ""Easy landing" on Baltimore Maryland's Inner Harbor," (2010).
[29] Pfammatter, *Building the Future : Building Technology and Cultural History from the Industrial Revolution until Today*: 84.
[30] Donald E. Ingber, "The Architecture of Life," http://time.arts.ucla.edu/Talks/Barcelona/Arch_Life.htm (accessed 17 January 2013).

benefits of "tensegrity" by stating that: "As architects, we are attracted to tensegrity structures for their visual lightness and their efficiency. They offer the maximum strength for a given amount of material, which keeps the member sizes slender and light." [31] The "tensegrity" method of construction pointed to a new direction in architecture construction and it continues to be used as an experimental method of construction, providing grounds for further research and practice.

1.4 The City of the Future – Mobile City Planning and the Plug-in City

The 1960s was a period of exciting, radical and subversive cultural and political events which sparked a social revolution throughout much of the Western world. Contemporary scholars pursued their visionary ideals of a better future, led by the application of technology towards social causes. Carolina Stevenson states that the architecture of this period aimed to harmoniously and creatively integrate human happiness, mobility and environment. Under this theoretical atmosphere, the "utopia of the modern nomad" reached its pinnacle with the radical European avant-garde movement of the 1960s and 1970s.[32]

One of the most representative examples is the inspiring work of Hungarian architect Yona Friedman, [33] who now lives in France. Lebesque and Helene Fentener van Vlissingen state that the work of Friedman, particularly in its first phase, termed "L'Architecture Mobile," [34] aimed to provide "maximum flexibility" [35] and has led architects, urban planners, theorists and researchers to a utopian world by

[31] Chris Wilkinson, "Responsive Structures,"(2001), http://www.wilkinsoneyre.com/texts/essays/responsive-structures.aspx (accessed 17 December 2012).
[32] Carolina Stevenson, "The Evolution of Temporary and Permanent Kinetic Architectural Structures" (paper presented at the International Association for Shell and Spatial Structures (IASS) Symposium 2010, Shanghai, China, Shanghai, 2010), 832.
[33] Yona Friedman was born in Budapest, Hungary, in 1923 and studied architecture at the Technical University, Budapest. One of his most important contributions is his theory of mobile architecture and the mobile city. According to Professor Alfredo Brillembourg – one of the directors at Urban Think Tank, who also holds the chair for Architecture and Urban Design at the Swiss Institute of Technology, ETH in Zürich – the only way to contact Friedman for interviews is by using fax machines, because he does not use the Internet.
[34] "L'Architecture Mobile" translates as Mobile Architecture.
[35] Sabine Lebesque and Helene Fentener van Vlissingen, *Yona Friedman : Structures Serving the Unpredictable* (Rotterdam: NAi Publishers, 1999), 9.

incorporating "principles based on the absolute requirement of individual freedom".[36] Friedman co-founded GEAM (The Groupe d'Études d'Architecture Mobile),[37] a group of young European architects and engineers who were all interested in structures and technical details.[38] The core ideas he proposed in the 1960s were that: "New constructions serving for individual shelters must: 1. Touch a minimum surface of the ground; 2. Be demountable and moveable; 3. Be transformable at will by the individual inhabitant."[39]

In addition to mobile architecture, Friedman also showed interest in urban design. In the Spatial City project (Figures 1.12. and 1.13.), Friedman was inspired by the housing shortage in France during the late 1950s, and "raised a second city fifteen to twenty meters above the existing one".[40] This project was "designed for construction anywhere, and meant to be adapted to any climate".[41] In a conversation with Larry Busbea, Friedman explained that GEAM was dissolved in 1962 because "other members were not developing their own ideas actively enough".[42] Busbea later argued that Friedman "elaborated his notion of mobility in architecture with an overabundance of obscure terminology and neologisms".[43] Friedman's interests in planning did not stop, and he seemed particularly keen on the theory that he called "the reasoning".[44] In his book *Toward a Scientific Architecture*, he states that the works from Schulze-Fielitz (1961), Kenzo Tange (1962), Kurokawa, the Archigram group, Safdie, Bofill and Mühlestein "were too much inspired by the kind of visualizations (drawings or photographs of models) that have appeared in professional journals since 1959",[45] and that "for the most part, these architects also did not understand that the forms which I proposed

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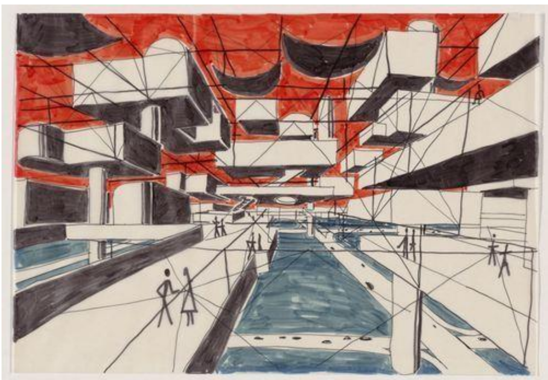
[36] Ibid.
[37] Their first group meeting took place in Rotterdam in 1958. The original members included Yona Friedman, David Georges Emmerich, Jean-Pierre Pecquet, Jerzy Soltan [Soltan was no longer associated with the group after the initial meeting] and Jean Trapmann, although other members, such as Werner Ruhnau, Günther Günsche, Frei Otto, Paul Maymont and Eckhard Schulze-Fielitz joined a few months later.
[38] Larry Busbea, *Topologies : The Urban Utopia in France, 1960-1970* (Cambridge, Mass.: MIT Press, 2007), 62.
[39] Yona Friedman, Program of Mobile Urbanism, in Ockman, Joan, and Edward Eigen. 1993. Architecture Culture, 1943-1968: A Documentary Anthology. [New York]: Columbia University Graduate School of Architecture, Planning, and Preservation, quoted in ibid.
[40] Howard Gilman, Terence Riley, and Art Metropolitan Museum of, *The Changing of the Avant-garde : Visionary Architectural Drawings from the Howard Gilman Collection* (New York: Museum of Modern Art, 2002), 40.
[41] Ibid.
[42] Busbea, *Topologies : The Urban Utopia in France, 1960-1970*: 64.
[43] Tatjana Schneider and Jeremy Till, *Flexible Housing* (Oxford, UK: Architectural Press, 2007), 4-5.
[44] Yona Friedman, *Toward a scientific architecture* (Cambridge, Mass.: MIT Press, 1975), ix.
[45] Ibid.

were only the result of this very strict reasoning”.[46] Busbea summarises part of Friedman’s contribution as:

> Friedman’s development of mobile architecture tapped into the national craze for bricolage, or the home repair and improvement projects that became popular during the fifties and sixties across Europe.[47] Friedman’s insistence that architects step aside and allow the users of urban infrastructures to have absolute and final say in the configuration of their dwellings was the futuristic extension of bricolage.[48]



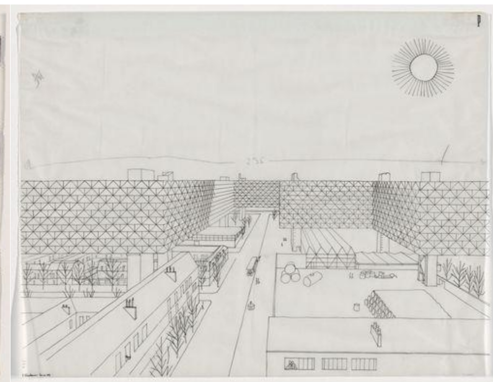


FIGURE 1. 12. - FIGURE 1.13. Spatial City, project, Perspective, 1958–59;[49] Spatial City, Elevated Blocks, project, Paris, France, Perspective, 1959[50]

Most of the methodology of Friedman’s architecture designs has the concept of buildings being flexible and mobile, with light components and plug-in units. Similar to Friedman’s findings, the representative work from Archigram also opened up the intellectual discussion behind the dynamism and freedom of this new type of architecture. The most famous project from Archigram is the Plug-in City, described hereby Peter Cook:

> The Plug-in City as a total project was the combination of a series of ideas that were worked upon between 1962 and 1964. The metal cabin housing was a prototype in the sense that it placed removable house elements into a “megastructure” of concrete. The discussion of *Archigram* 2 and 3 built up a pressure of argument in favour of expendable building: and it was then inevitable that we should

[46] Ibid.
[47] Yona Friedman, L'architecture Mobile, quated in Busbea, *Topologies : The Urban Utopia in France, 1960-1970*: 73.
[48] Ibid.
[49] Yona Friedman, "Spatial City, project, Perspective," in *The Museum of Modern Art (MoMA), Architecture and Design collection* (1958-59).
[50] ———, "Spatial City, Elevated Blocks, project, Paris, France, Perspective," in *The Museum of Modern Art (MoMA), Architecture and Design collection* (1959).

> investigate what happens if the whole urban environment can be programmed and structured for change.[51]

At the same time as Archigram, a Japanese avant-garde group, Metabolism,[52] also designed flexible and expendable structures that evoked the processes of a city's growth. The Metabolists had similar ideas to Archigram about megastructures, and they promoted their ideas through live projects such as the Nakagin Capsule Tower in Tokyo designed by architect Kisho Kurokawa and completed in 1972, which consisted of individual components that could be removed or replaced.[53]

This avant-garde movement[54] introduced revolutionary concepts for a new way of construction and living which, in turn, reinforced the integration of mobility and speed within architecture. French architectural historian, Françoise Choay, believes that at the end of 20th century, the era of electronics and telematics caused the disappearance of utopia. She states that this phenomenon can be explained by the underlying obliteration of this dualism in favour of a mono-space. The same outcome also prompts us to ponder on the nature of this mono-space and the implications of its spread worldwide.[55] Many of the utopian ideas were based on and inspired by the reality of the post-Second World War period, when many countries were recovering and developing new cities. Utopian ideologies had a deep impact on the aspects of social space to cultural landscapes, and from that time until today.

[51] Peter Cook, "Plug-in City," in Martin van Schaik and Otakar MÃ¡cel, *Exit utopia : architectural provocations, 1956-1976* (Munich: Prestel, 2005), 77.
[52] The architecture group "Metabolism" was established in Japan in the late 1950s by a group of young Japanese architects and designers. Their work was concerned with housing issues in Japan and with a version of future cities inhabited by a mass society that evoked the process of organic growth.
[53] Carsten Krohn, "Mobile Houses Buckminster Fuller's Concept of a Dynamic Architecture," In Muller, *Arctic Perspective Cahier No. 1*: 92-93.
[54] Avant-garde is a French term that has been widely used in the English language to refer to people and works that are experimental or innovative in arts, architecture, culture and politics.
[55] Francoise Choay, "Utopia and the Anthropological Status of Built Space," In Schaik and MÃ¡cel, *Exit utopia : architectural provocations, 1956-1976*: 99-100.

1.5 Trends in Contemporary Demountable Buildings

Prefabricated housing and portable buildings have, in the past, often been considered low quality and cheap construction choices. From the end of the 20th century up to the present day, a renaissance in demountable buildings has been seen, particularly for exhibitions and public event use, combining new technology with building design. Evidence can be seen from many world famous architects, designers and artists, for example, Shigeru Ban's Nomadic Museum and paper structure pavilions.[56] Iraq-born British architect Zaha Hadid has designed three demountable and mobile buildings to date: The Burnham Pavilion, temporarily erected in Chicago's Millennium Park as part of the Burnham Plan celebrations in 2009; The Egypt Pavilion, an elegant and temporary structure exhibited during the Expo 2010 in Shanghai, China, where the architectural part is related to a single, enveloping fabric ribbon that continues from the façade into the building and exhibition; and the Chanel Mobile Pavilion, which travelled from Hong Kong to Tokyo and New York, before setting in Paris.

Shigeru Ban and Zaha Hadid are professionally trained architects but, as well as architects, designers and artists have also designed extraordinary demountable buildings and structures, with British designer and artist Thomas Heatherwick, recently designing the Olympic Cauldron for the London 2012 Olympic Games. The Heatherwick Studio states that "the 2012 cauldron will cease to exist. Like a flower that only blooms for the duration of the competition, it is a temporary representation of the extraordinary transitory togetherness that is an Olympic Games."[57] The Olympic Cauldron opened out and divided into its constituent objects at the close of the Games. Each country was able to take its own object as a souvenir of the most exciting sporting event of 2012.

Similar examples can also be found from small innovative research groups, such as the ICD (Institute for Computational Design)/ITKE (Institute of Building Structures and Structural Design) Research Pavilion, built between 24 June and 23 July 2010. This was a temporary pavilion constructed from plywood strips which was manufactured in the

[56] Shigeru Ban's recent paper tube constructions include: Japan Pavilion at Hannover Expo, Germany (2000); Paper Theatre at Amsterdam, Holland (2003); Vasarely Pavillion at Aix-en-Provence, France (2006); Singapore Biennale Pavilion, Singapore (2006); Papillion Pavilion at Champs Elesees, Paris, France (2006); Paper Tower, London, UK (2009); and Japan Industry Pavilion, Theme Show Hall at Shanghai Expo, China (2010). More details can be read in Chapter 2: Terms of Reference.
[57] Heatherwick Studio, "Olympic Cauldron," http://www.heatherwick.com/2012-olympic-cauldron/ (accessed 24 August 2012).

University of Stuttgart. More projects can be seen in the Serpentine Gallery commission – a programme of temporary structures by celebrated architects, designers and artists. Twelve unique temporary pavilions have been built so far, designed by Zaha Hadid (2000), Daniel Libeskind with Arup (2001), Toyo Ito and Cecil Balmond with Arup (2002), Oscar Niemeyer (2003), Alvaro Siza and Eduardo Souto de Moura with Cecil Balmond from Arup (2005), Rem Koolhass and Cecil Balmond with Arup (2006), Zaha Hadid Architects (2007), Olafur Eliasson and Kjetil Thorsen (2007), Frank Gehry (2008), Kazuyo Sejima and Ryue Nishizawa of SANAA (2009), Jean Nouvel (2010), Peter Zumthor (2011), and Herzog and de Meuron and Ai Weiwei (2012).[58]


FIGURE 1.14. - FIGURE 1.15. The Burnham Pavilion;[59] London 2012 Olympic Cauldron[60]

The dynamic form of contemporary demountable buildings introduces many questions, including what role demountable buildings have today. Robert Kronenburg states, in his book *Portable Architecture*:

> Contemporary architecture has now to respond to significant influences that were deemed relatively unimportant until recently. Ecological considerations that measure the use of renewable resources, recyclable components, and building costs on a life-cycle basis are now enormously significant. The societal impact of development, particularly in urban areas, is now a dominant factor as is the context of sensitive and historic sites.[61]

Demountable buildings can meet and reduce all of the pressures mentioned above. Moreover, the key features of contemporary demountable buildings and structures

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[58] Serpentine Gallery, "Architecture," http://www.serpentinegallery.org/architecture/ (accessed 24 August 2012).
[59] Roland Halbe, "Burnham Pavilion," ed. Burnham Pavilion (2009).
[60] Heatherwick Studio, "Olympic Cauldron," (2012).
[61] Robert Kronenburg, *Portable architecture : design and technology* (Basel; London: BirkhÃ¤user ; Springer [distributor], 2008), 10.

include: diverse forms of building, reflecting the developments in new technology, materials and construction skills; the blurring of the boundaries between architecture, functional structures, objects such as furniture, sculptures and installations, because many of them share similar meanings and forms; and more cross-disciplinary collaborations between architects, engineers, designers, artists, computer programmers and scientists, working together towards a shared aim with related interests. The concept of demountable buildings has developed gradually, incorporating evolving new configurations that take into account ecological considerations, contemporary social context, technology capacity and economic demands.

Ecological Considerations

Contemporary conversations about sustainability and ecological considerations with respect to architecturally related areas are based on the idea of sustainable development, outlined by the Brundtland Commission in 1987: that the needs of the present society should be met without compromising the ability of future generations to fulfil their own needs.[62] According to the Commission, the key elements of sustainability that need to be reconciled are:

- sufficient growth of energy supplies to meet human needs (which means accommodating a minimum of 3 per cent per capita income growth in developing countries);
- energy efficiency and conservation measures, such that waste of primary resources is minimized;
- public health, recognizing the problems of risks to safety inherent in energy sources; and
- protection of the biosphere and prevention of more localized forms of pollution.[63]

Scientist and architect Rachel Armstrong argues in her recent digital book, *Living Architecture*, that the present environmental challenges and worldwide population growth demand an improved system for human development and, in today's commercial climate, the term "sustainability" implies preserving the use of industrial technologies in development rather than embodying vital changes in the production of

[62] The Brundtland Commission focused on areas of population, food security, the loss of species and genetic resources, energy, industry, and human settlements. According to the Commission, these areas are all connected and cannot be treated in isolation one from another.
[63] Environment World Commission on and Development, *Our common future* (Oxford [u.a.]: Oxford Univ. Press, 2009), 169.

architecture.[64] She believes that current ecological design research has been subsequently based on empirical measurements that evaluate building performance, such as energy efficiency and post-occupancy assessments, which take a particular view of sustainable architecture as that which relates to the consumption of fossil fuels, and replaces this energy source with the harnessing of renewable energy.[65]

In response to ecological considerations, all demountable buildings contain reusable and recyclable components. They are generally derived from permanent building construction techniques and can take many diverse forms. Demountable buildings of this type use familiar, bolt-together components in order to produce a building that can also be disassembled for relocation.[66] More directly, many demountable buildings can be constructed with recyclable materials such as paper tubes and cardboard, and renewable materials such as wood, timber, bamboo and even large snow blocks. In particular, small-scale projects require relatively fewer construction materials and energy costs, thus having less impact on the environment. It can be argued that the design and use of small-scale public demountable buildings can greatly encourage the eco-efficiency of the architectural industry by reducing the energy intensity of goods and services, enhancing the recyclability of materials and maximising sustainable use of renewable resources.

Social Context

In response to societal impact, demountable buildings are often used for temporary emergency needs. They can represent a better choice for engaging the public and traditional demountable structures, such as tents, remain useful for responding to disaster mitigation projects. For example, UNESCO (United Nations Educational, Scientific and Cultural Organization) supported a theatrical project with Haitian street theatre company Zhovie to give displaced people in Port-au-Prince a moment of joy and solace and help to relieve their fears after the earthquake of 12 January 2010. Zhovie

[64] Rachel Armstrong, "Living Architecture How Synthetic Biology Can Remake Our Cities and Reshape Our Lives" (New York, 2012), 51.
[65] Ibid.
[66] Kronenburg, *Houses in Motion*: 78.

gave their first performance on 11 April 2011 in a camp at the Haitian capital to an audience of several thousand.[67]

FIGURE 1.16. The Haitian street theatre Zhovie in performance[68]

As well as being used in emergency situations, demountable buildings and structures also respond to new social issues such as urbanisation. UN-Habitat (The United Nations Human Settlements Programme)[69] reports that the world is moving into the urban age,[70] and United Nations Executive Director, Joan Clos, states that a new type of city is advocated that is a "good", people-centred city, capable of integrating the tangible and more intangible aspects of prosperity and, in the process, shedding the inefficient, unsustainable forms and functionalities of the city of the previous century.[71] By doing so, businesses, academics, civil society, non-governmental and grassroots organisations, trade unions and professional associations, and political parties need to respond to the situation and bring their contributions to cities. One of the solutions proposed by UN-Habitat is to encourage social diversity and mixed land-use. Land planning can bring

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[67] United Nations Educational, Scientific and Cultural Organization United Nations Educational, "UNESCO Organizes Theatre Performances for Displaced People in Haiti.".
[68] "UNESCO Actions for Haiti," in *Culture & Traditions (Videos)* (2011).
[69] UN-Habitat is the United Nations agency for human settlement. Their work includes Urban Development Management, Land and Housing, Environment and Climate Change, Water Sanitation and Infrastructure, Urban Economy and Financing Shelter, Risk and Disaster Management, Social Inclusion, and Information and Monitoring. It produces annual reports, along with handbooks and guidelines, for governments, local authorities, donors, professionals and researchers. Its regional centres are called 'United Nations Centre for Human Settlements' (Habitat)/(UNCHS).
[70] United Nations Human Settlements Programme (UN-HABITAT), "State of the World's Cities Report 2012/2013: Prosperity of Cities,"(2012), http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3387 (accessed 15 January 2013).
[71] Ibid., 4.

about clusters of land uses in appropriate locations, with the flexibility needed to adapt to the changing requirements of the population. Urban planning must facilitate the deployment of common spaces that allow encounters, interaction and dialogue between different social and ethnic groups. The report gives the example of the Olympic Park for the 2012 Olympics Games in Stratford, London, which was constructed on brownfield sites that had previously become rundown. Following the conclusions of the Olympic Games, the site is to be used to accommodate low-cost housing as well as leisure activities. This emphasises the fact that demountable structures and buildings can inhabit land in a sustainable manner by occupying sites for a relatively short time.

Therefore, it can be argued that contemporary demountable buildings continue to respond to disaster mitigations by offering emergency shelter solutions quickly. At the same time, demountable buildings and structures have great potential to encourage mixed land-use, because their construction requires no, or light foundations, and they can be erected in many different locations.

Technology Capacity

Nick Dunn[72] states that with the development of CAD (Computer-Aided Design) and many other software packages, concluding Rhino 3D, DesignBuilder and Autodesk Robot Structural Analysis, the variety of design processes available to architects may influence the fabrication of architecture and its components.[73] Such technology has recently been successfully utilised for demountable buildings and structures, for example, Zaha Hadid's Mobile Art Pavilion for Chanel which took advantage of digital imaging and construction processes to create a design with fluid geometries and dynamic spaces.[74] Another temporary installation design by Hadid – the Burnham Pavilion, Chicago – also represents the use of digital fabrication technology in a demountable structure. The pavilion comprises bent aluminium structural sections, each shaped and welded to create its unique curvilinear form. Outer and inner fabric skins wrap tightly around the metal frame to create a fluid shape, and these skins also

[72] Nick Dunn is a lecturer at the School of Architecture, University of Manchester. His doctoral thesis "The Ecology of the Architectural Model" (2005) is concerned with developing a new methodology and system of diagrams with which to study and map the design behaviour of architecture students and, therefore, contribute to the understanding of the complex process of design.
[73] Nick Dunn, *Digital Fabrication in Architecture* (London: Laurence King, 2012), 6.
[74] Ibid., 7.

serve as the screen for video installations. The project aimed to maximise the recycling and reuse of materials after its role in Millennium Park and, it can be installed for future use at another site.

The Fabricate Conference, hosted by UCL (University College London) Bartlett School of Architecture, London in April 2011, presented Gramazio & Kohler's installation *Stratifications*, which was a cutting-edge, assembling method first revealed in the UK. The installation presents a research project of using CNC robotic arms to construct a brick installation. A similar research project – Flying Machine Enabled Construction at ETH (The Swiss Federal Institute of Technology Zürich) Campus in Zürich – pushes the construction of demountable buildings to a new era. The focus of this project is the assembly and construction of structures using flying vehicles, the system is built on the Flying Machine Arena[75] platform, with specific components developed to manage and perform construction. The first use of the Flying Machine Enabled Construction paradigm is the installation titled *Flight Assembled Architecture* at the FRAC Centre Orleans. This installation was developed jointly with architects Gramazio & Kohler, the 6m-high installation addresses radical new ways of thinking and materialising architecture as a physical process of dynamic formation (Figures 1.17. and 1.18.).

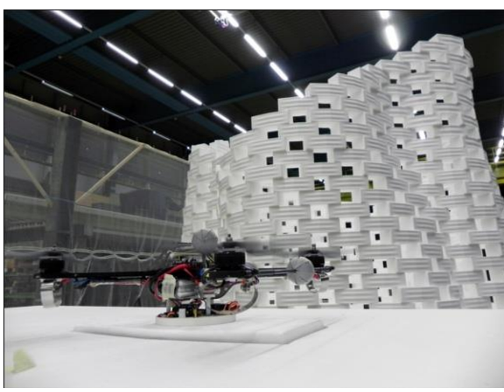

FIGURE 1.17. - FIGURE 1.18. A preliminary version of the structure built at ETH Zürich; the structure and the crew[76]

Using flying machines and robots for construction enables building alternative possibilities to be achieved. The ability of being quickly assembled and deployed is

[75] The Flying Machine Arena is a 10m^3 indoor space, with an additional control room attached. It offers a safe and controlled sandbox environment allowing the testing and validation of mobile robots, and used in a range of projects carried out at the Institute for Dynamic Systems and Control and other research laboratories.
[76] Autonomous Systems Raffaello D'Andrea: Control of Distributed, "Flying Machine Enabled Construction," (2011).

becoming an important requirement, not only for traditional demountable buildings, but also for new conventional buildings. It can be argued that the use of demountable structures and buildings encourages designers to rethink design and construction processes to require an easy dismantling process. According to Matthias Kohler, an effective way to work on the contemporary reality of architectural design and construction is neither low-tech nor high-tech, but involves working with generic technologies, such as industrial robots or computers, as they can easily be customised for a variety of processes and are inexpensive.[77]

The various choices of construction methods provide dynamic aesthetic forms for demountable structures and buildings. In this digital age, the technological capacity of a project is strongly linked with the collaboration between multidisciplinary teams, including designers, structural engineers and contractor teams. Although the advantages and disadvantages of digital fabrications are yet to be explored further, evolutionary design methods have a strong potential to allow designers to work on more sophisticated digital fabrication projects in comparison to traditional architecture and industrially built architecture.

Economic Demands

The design and use of contemporary public demountable buildings are largely related to the creative industry.[78] For example, the Spanish Pavilion of Shanghai Expo 2012 was clad with wicker panels, which were made in a rural village in China. The local authority claims that the project brought $11,700,000 of benefits to the village, because their skills in making wicker panels were recognised through events of the Expo.

According to the NESTA (National Endowment for Science, Technology and the Arts) Policy and Research Unit, the economic contribution of the creative industries is widely recognised, and plays an important role in the UK. In fact, the UK has the largest creative sector in the European Union, arguable the largest in the world relative to GDP (Gross Domestic Product). The most recent statistics for the creative industries,

[77] Matthias Kohler, "Q&A," In Bob Sheil and Ruairi Glynn, *Fabricate : Making Digital Architecture* (Toronto: Riverside Architectural Press, 2011), 118.
[78] The thirteen creative industry sectors defined by the Department for Culture, Media and Sport in 1998 are: advertising; architecture; arts and antiques; market crafts; design; designer fashion; film; interactive leisure software; music; the performing arts; publishing; software and computer services; and television and radio.

published in December 2011, show that they contributed 2.9% of the UK's Gross Value Added in 2009, and that 1.5 million people are employed in the creative industries or in creative roles in other industries, making up 5.1% of the UK's employment. In addition to this, the IDBR (Inter-Departmental Business Register) showed an estimated 106, 700 businesses in the creative industries in 2011.[79]

In summary, contemporary demountable buildings currently need to respond to ecological issues, social impacts, technology innovation and economic demands. Social issues, particularly in urban areas, relate to sustainable land use, reusable building components and temporary employment. Technology innovation relates specifically to the design method, construction process and the use of selected materials. The economic demands have particularly strong impacts on the creative industry and small groups of entrepreneurs and therefore, it can be argued that contemporary demountable buildings can be used to measure a society's development in environmental sustainability, technology innovation and economic growth through various forms.

1.6 Research Scope and Questions

The evaluation of functional performance in small-scale demountable buildings is a broad subject, which includes many different aspects. For example, the function of a demountable school project is different from that of an exhibition project, and this can be seen through the use of time, user groups and acoustic performance requirements. This research focuses primarily on the study of contemporary demountable buildings and existing evaluation and analysis methods. This subject was chosen after a comprehensive study of the available literature, where a large amount of information regarding the functional capabilities of this particular type of building is evident, but, other architectural and structural qualities have been rarely studied. The main research question concerns how functional performance in small-scale public demountable buildings can be evaluated, addressing issues of built environment, social

[79] Department for Culture Media and Sport, "Creative Industries Economic Estimates - Full Statistical Release,"(2011), http://www.culture.gov.uk/images/research/Creative-Industries-Economic-Estimates-Report-2011-update.pdf (accessed 16 January 2013).

considerations and economic effects. In order to do so, this research focuses on three particular aspects of the evaluation of demountable buildings.

1. **How can the evaluation indicators of demountable buildings be identifed?**

The purpose of this question is to clarify the research context through analysing the terms that are related to the area of interest: small-scale, public and demountable buildings. This helps to analyse the key features and benefits of contemporary demountable buildings and, their role in architecture and industry. This requires a wide range of archival research when searching for examples of contemporary demountable buildings that have been successfully inhabited or visited by a broad audience.

One of the main difficulties of this research is to establish a set of criteria for assessing functional performance in small-scale public demountable buildings. This requires a circumstantial analysis of the key factors in the design and operation of this type of building. It is also important to be coherent about the purpose of the evaluation, who the evaluator is, and how the results of the evaluation can be useful for architects and, eventually, the project owners.

2. **What can be learnt from existing evaluation methods in the relevant areas?**

It is important to first identify whether there are any existing evaluation and analysis methods that have been utilised in demountable buildings or similar building types. Due to the nature of demountable buildings, there are many building components that can be understood as separate products. If there are a number of methods that appear to be applicable, it is essential to choose the most suitable method for the evaluator to use.

3. How can the knowledge of demountable buildings and the knowledge from the evaluations be combined?

The most essential part of this thesis is to combine what has been learnt from demountable buildings and existing evaluation methods. This forms an important component of this research through the transfer of knowledge between different fields. To tackle this, an evaluation conceptual model will be designed, which covers the evaluation indicators that represent the functional performance of demountable buildings, and allows the relevant evaluation methods to be adapted and utilised.

1.7 Research Hypothesis, Aim and Objectives

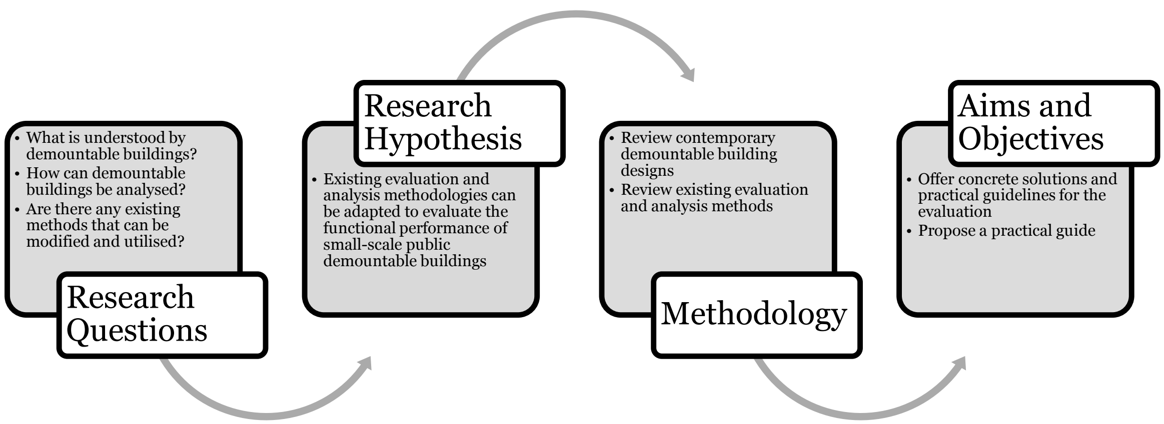

FIGURE 1.19. Research hypothesis, aim and objectives

The research hypothesis is that existing evaluation and analysis methods can be adapted to evaluate the functional performance of small-scale public demountable buildings. The research aims to offer concrete solutions and practical guidelines that enable functional performance and evaluation scenarios to be tested through three case studies that represent the characteristics of small-scale public demountable buildings.[80] The

[80] The features of the demountability of this type of building, such as packaging for delivery, adaption, structural efficiency and potential modification are an important consideration that would be part of any ongoing investigation regarding design and construction phase performance. However, the demounatability and mobility aspects were not included as a part of functional performance for evaluation in this thesis because the author primarily focuses on the functional performance in operations from the users' perspective and they would have little concern or knowledge about deployment aspects.

main challenges are: to identify the meaning of the research topic; to classify the existing evaluation and analysis methods from related fields; and to adapt the methods through case studies.

In order to achieve this aim and respond to the challenges, a number of objectives have been formulated to guide the research:

(i) To review contemporary demountable building designs to provide a systematic understanding of this building type. This will also outline how the wider lessons of demountable buildings may be employed in future research.

(ii) To review existing analysis and evaluation methods, including standards, software, new technology and multi-dimensional methods that have recently been developed in related fields. The purpose of this review is to study a methodology that has been successfully practised, hence collecting empirical information regarding demountable buildings.

(iii) To propose a practical guide or conceptual model for evaluation and to prepare to test this through a series of case studies.

(iv) To study a series of carefully chosen case studies of demountable buildings that have been built by international architects and designers. They will be used as part of the research strategy to examine the conceptual model as a result of the previous objective.

1.8 Methodology

Abraham Kaplan defines the aim of methodology as being to "describe and analyse these methods, throwing light on their limitations and resources, clarifying their presuppositions and consequences, relating their potentialities to the twilight zone at the frontiers of knowledge".[81] In this thesis, the methodology is the philosophical principle that helps to shape all methods utilised and illuminate the research process.

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[81] Abraham Kaplan, *The Conduct of Inquiry: Methodology for Behavioral Science* (San Francisco: Chandler Pub. Co., 1964), 23.

This section provides an overview of the methodology adopted during the course of the research, with both quantitative and qualitative research techniques identified to address the research gaps mentioned in the introductory section. This research can be categorised into five phases: literature review; field research; case studies; interviews; and focus group discussions and public discussions.

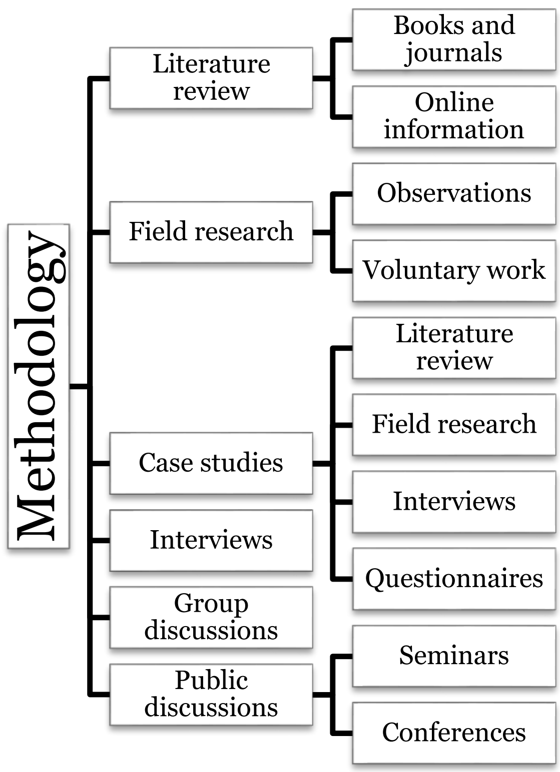

FIGURE 1.20. Research methodology diagram

1.8.1 Literature Review

In this research, the literature review has multiple purposes. It provides a brief historical background of demountable buildings and similar architecture types, as presented in Chapter 1. It gives an overview of the current context in which the evaluation of demountable buildings is situated, by referring to contemporary debates, issues and questions within the broader field and, it introduces relevant terminology and provides definitions of key terms, which are in Chapter 2. In Chapter 2 and 3, there is a discussion of the relevant theories and concepts that underpin this research, and describes related research in the field, identifying a gap within the work that is addressed by this research. Finally, in addition to this section, the evidence from sources including books, journal articles and reports can also be read throughout the thesis, in support of evidence for the practical issues directly addressed here.

This literature review aims to outline the development of contemporary worldwide demountable buildings in general, as well as in specific areas that are directly related to the research title. It has been divided into two sections, with the first briefly discussing the history of demountable buildings, covering a wide range of building types, including portable and relocatable building types. The second section initially explores contemporary existing demountable buildings to establish a set of criteria covering the key factors of design and operation, before assessing existing analysis/evaluation methods that have been successfully implemented to collect empirical information. The literature review includes books, journal articles, electronic books/articles, magazines and literature, and *grey literature* – which refers to "the material that is not published commercially and is difficult to obtain through the usual book selling".[82] In this thesis, this includes conference proceedings, reports, theses and dissertations, posters, leaflets, personal communication, media, short films, online databases and online information.

Key references for the history and development of the field were reviewed, with a focus on texts by Robert Kronenburg who has made a significant contribution to the understanding of moveable buildings, including portable, relocatable and demountable buildings. In his book *Houses in Motion* (1998, 2002), Kronenburg introduces the prehistoric and traditional portable building and non-architectural precedents, followed by a discussion of 20th century inventions and contemporary designs. Shelter after disasters and utopian ideas, such as those from Archigram, are also discussed alongside illustrations. He emphasises the importance of portable architecture that appears to address newly recognised environmental issues, such as ecological awareness and sustainability.[83] In his book *Flexible: Architecture that Responds to Change* (2007), Kronenburg examines flexible architecture from two perspectives. The first section explores the historical context and the impacts of flexible design, especially on contemporary architecture. The second section organises four essential characteristics of flexible architecture: adaptation, transformation, movability and interaction.[84] In contrast to *Houses in Motion*, this book reflects on both mobile and non-mobile

[82] Diana Ridley, *The Literature Review : A Step-by-Step Guide for Students* (London; Thousand Oaks, Calif.: SAGE, 2008), 32.
[83] Kronenburg, *Houses in Motion*: 150.
[84] ———, *Flexible : architecture that responds to change* (London: Laurence King, 2007), 7.

architecture, where the term *flexible* is considered most suitable. In book *Portable Architecture: Design and Technology* (2008), Kronenburg categorises portable architecture into five groups according to its specific function: exhibition and commerce, entertainment, shelter and residential, arts and education, and military and expedition. In each group, he lists a series of contemporary and representative projects to examine the particular use, design and technology of portable architecture. Each example is presented with clear images and detailed architectural drawings to illustrate how design and technology were utilised through construction, use and deployment. Most recently, in *Live Architecture: Design and Technology* (2012), he explores the designs of popular music performance spaces, with particular attention paid to recent developments that have changed the form and operation of permanent venues and travelling stages. The examples used discuss the "factors that determine the architectural form of live performance space",[85] and he "examines specific examples that range from small music clubs to large and complex stadium sized buildings".[86]

Jennifer Siegal[87] has also contributed to mobile architecture through design and research, and is well known for her work on the creation of the prefab home of the 21st century. Her innovative mobile structures include customised prefab, green modernist homes and she is the editor of both *Mobile: the Art of Portable Architecture* (2002), and *More Mobile: Portable Architecture for Today* (2008). In *More Mobile*, Siegal introduces a wide range of creative "ideas that are not traditionally found in the pedagogy of architectural education".[88] She introduces work from small-scale projects, such as Dré Wapenaar's[89] *Treetents* (Figure 1.21.), Andreas Vogler's[90] *DesertSeal* (Figure 1.22.), and work from Japanese architecture group Atelier Bow-Wow, whose experimental projects with micro public spaces have been exhibited across the world.[91]

[85] ———, *Live Architecture : Venues, Stages and Arenas for Popular Music* (Abingdon, Oxon; New York: Routledge, 2012), 3.
[86] Ibid.
[87] Jennifer Siegal is an editor and a designer who has a long history of interest in mobile architectural design. She founded the company Office of Mobile Design in 1998 in Los Angeles.
[88] Jennifer Siegal, *More Mobile : Portable Architecture for Today* (New York: Princeton Architectural Press, 2008), 10.
[89] Studio Dré Wapenaar is based in Rotterdam, Holland. Their work covers sculptures and installations, mainly in tent and pavilion form.
[90] Andreas Vogler was born in 1964 and he is a Swiss architect and designer, and the co-founder of the architecture and design practise Architecture and Vision.
[91] More details about the work from Atelier Bow-Wow and their "pet architecture" ideas are discussed in Chapter 2: Terms of Reference.

FIGURE 1.21. - FIGURE 1.22. The Treetents;[92] The prototype of DesertSeal, exhibited at MoMA (Museum of Modern Art), New York since 2005

John Chilton contributes to the debate on lightweight construction technology from various aspects: structure (especially in tensile, membrane, deployable, shell and space grid structures), materials (especially in timber, wood and plastic membrane); and construction industry (especially in environmental control and the implications of climatic design in lightweight structures). In *Space Grid Structures* (2000), Chilton examines the space grid structures with regards to its history, structural systems, materials, design and construction. A comprehensive range of projects are assessed as case studies, to demonstrate how they can be used to produce aesthetically pleasing and efficient buildings.[93] Recommendations for further development are also proposed.

There are many other academics, designers, research groups and writers who have explored the designs, technology and functions of building types containing demountable components. Philip Jodidio's *Temporary Architecture Now* (2011)*,*[94] briefly introduces contemporary temporary architecture projects with clear illustrations, including project photos and architectural drawings. Despite its general descriptive manner, the book is a collection of the innovative designs of current active architects and designers, and provides a useful reference point for identifying valuable information on temporary architecture projects.

[92] Robbert R. Roos, "Treetents," ed. Treetents (1998).
[93] John Chilton, *Space Grid Structures* (Oxford, UK; Boston, Mass.: Architectural Press, 2000), 61.
[94] Philip Jodidio, *Temporary Architecture Now! = Temporäre Architektur heute! = L' architecture éphemère d'aujourd'hui!* (Köln u.a: Taschen: Taschen, 2011). Philip Jodidio was educated at Harvard University. He is an internationally renowned editor who has wide interests in architecture. His books include Taschen's *Architecture Now!* series and monographs on world famous architects Tadao Ando, Norman Foster, Jean Nouvel, Richard Meier, Zaha Hadid and Shigeru Ban.

With a more specific focus, architect and Professor, Han Slawik, of Experimental Design at Leibniz Universität Hannover (The University of Hannover), and his team, researched the phenomenon of container architecture through its form and structure, and have provided many more details on usage, type, construction, production, transportation, variants and economic aspects. In his illustrated book, *Container Atlas: A Practical Guide to Container Architecture*, a number of contemporary container architecture types are introduced, from standard shipping models to modular construction systems, listing examples that cover different functions from exhibitions and offices to stores and residential containers. Slawik and his team also provide a list of company names that have designed container architecture in the past and present, as well as making a glossary available that cover definitions such as the ISO Container – a freight container that fulfils the specifications of the ISO 668 standard,[95] and technical terms relating to container architecture construction. This book can be used for researchers or designers for reference on whether a container building can fulfil their needs for their upcoming projects.

Another interesting group is The Arctic Perspective Initiative, which is a not-for-profit international organisation founded by Marko Peljhan and Mathew Biederman. They are interested in the human infrastructures and architectural designs in the circumpolar region, with an aim of learning from local Arctic residents through open source technologies and applied education activities. Two of their most representative publications are *Arctic Perspective Cahier No. 1 – Architecture* (2010)[96] and *Arctic Perspective Cahier No. 2 – Arctic Geopolitics & Autonomy* (2011).[97] In contrast to this research, which explores temporary and demountable buildings as an individual subject, the Deputy Chief Executive of the London Chamber of Commerce and Industry, Peter Bishop, in collaboration with Lesley Williams, focuses on temporary urbanism in the context of economic, legislative and social conditions.[98] Many examples of "temporary activities" are presented, including pop-up shops, temporary art installations, street artwork, mobile cafés and protest activities. The broad case studies in *The Temporary*

[95] ISO 668: 1995 Series 1 Freight Containers – Classification, Dimensions and Ratings. This standard is based on external dimensions and specifies the associated rating and the minimum internal and door-opening dimensions for certain types of containers.
[96] Muller, *Arctic Perspective Cahier No. 1.*
[97] Michael Bravo and Nicola Triscott, *Arctic Perspective Cahier No. 2. ; Geopolitics and Autonomy* (Hatje Cantz Verlag GmbH & Co KG, 2011).
[98] Peter Bishop and Lesley Williams, *The Temporary City* (London; New York: Routledge, 2012), 6.

City are detailed but, as London-based writer Tim Abraham[99] argues, there is a lack of confidence in the city's future in both financially and ecologically.[100]

In addition to reviewing these key publications, it was necessary to read related conference proceedings. There have been several international conferences and workshops held on the theme of portable architecture, including demountable and transportable buildings. These conferences include "Transportable Environments 2001", hosted by the Department of Architecture, School of Design and Environment at the National University of Singapore on 17–18 May 2001 and "Transportable Environment 2004" in Toronto, Canada, organised by Ryerson University, Toronto in collaboration with the University of Liverpool on 28–30 April 2004. The subsequent publications provide an important resource for wider research areas including the history and theory of ephemeral architecture, structure design in kinetic architecture and technological innovations.

More recently, the "International Holcim Forum for Sustainable Construction on Re-inventing Construction (2010)", also hosted a selection of papers relating to temporary and demountable architectural objects. The conference took place in April 2010 at the Universidad Ibéroamericana in Santa Fé, Mexico City, and led to the publication of *Re-Inventing Construction*, edited by Ilka Ruby and Andreas Ruby. An important contribution to this book is "An Illustrated Index of Re-inventing Construction",[101] which was compiled and drawn by Something Fantastic,[102] written by Jessica Bridger, and has additional contributions from Mei Li, Forrest Meggers and Udo Thönnissen. This index contains a large amount of architectural terms directly linked to the conference topic and it encompasses idiosyncratic techniques, technologies and typologies, as well as materials that challenge the standards in construction of both traditional and contemporary architecture. The editors effectively launched a website called *Whatwow*[103] as a platform for collecting and sharing the re-invention of construction ideas, reflecting on the conference and the book. The index is a rich

[99] Tim Abraham is a writer and editor of *Blueprint* magazine and he has written on architecture and design for *Architecture Today*, *Architects' Journal* and *Icon*. He interviewed Yona Friedman in 2009 for the *Blueprint* magazine, and the article can be found in the July 2009 issue of *Blueprint*.
[100] Tim Abrahams, "The Temporary City by Peter Bishop and Lesley Williams," The Architects' Journal, http://www.architectsjournal.co.uk/culture/-the-temporary-city-by-peter-bishop-and-lesley-williams/8628139.article (assessed 22 September 2012)
[101] Ilka Ruby and Andreas Ruby, *Re-inventing construction* (Berlin: Ruby Press, 2010), 95-354.
[102] Something Fantastic is an architectural practice in Berlin, Germany. The company principals are Julian Schubert, Elena Schuetz and Leonard Streich, who were educated at ETH Zürich and the University of Arts Berlin.
[103] The Whatwow website is available at: http://whatwow.org/.

resource for relevant terms, such as “house inside a house”, “pop-up restaurants”, “recycled buildings” and many others.

Although the available literature supported an understanding of the characteristics of demountable buildings, there was a lack of evidence to suggest an accessible evaluation method that could address the issues of how the requirements of the design brief can be achieved. There was also little evidence to prove that the project operators have a systematic list of criteria to address the functional performance from a public perspective by reflecting on the ambition of their projects. Therefore, it was important to review the existing analysis and evaluation methods in related areas, to identify the key features of the method that have been successfully utilised in evaluating projects and buildings.

Yehuda E. Kalay’s book, *Architecture New Media* (2004), and John Kelly et al.’s edited book, *Best Value in Construction* (2002), provide valuable information for understanding the evaluation process, especially in relation to the architecture design and construction process. Stewart Brand’s *How Buildings Learn: What Happens After They’re Built* (1995), was particularly useful in explaining the lifespan of buildings and the key factors that influence a building’s design – *site*, *structure*, *skin*, *service*, *space plan* and *stuff*.[104]

With regards to the methods developed by city councils and cultural sectors, *Temporary Building Design Guide* by Aberdeen City Council (2008) and *Temporary Structures in Historic Places (Guidance for Local Planning Authorities, Site Owners and Event Organisers)* by English Heritage (2010) were reviewed as a result of the accessibility of the available documents.

With regards to methods in humanitarian response, *United Nations Centre for Human Settlements (Habitat) Guidelines for the Evaluation of Post Disaster Programmes* (2001); *Beyond Shelter: Architecture and Human Dignity* (2010) edited by Marie Jeannine Aquilino; *The Emergency Market Mapping and Analysis Toolkit* (2010) by Mike Albu; *Shelter after Disaster* and the document *Tearfund Shelter and Reconstruction Standards* (2010) by Ian Davis; *Toolkit: A Practical Guide to Planning, Monitoring, Evaluation and Impact Assessment* (2003) by Louisa Gosling and Mike Edwards; *ASPIRE: A Sustainable Poverty and Infrastructure Routine for Evaluation*

[104] See Chapter 3 for further discussion of site, structure, skin, service, space plan and stuff.

by Arup; and *Indicators for Measuring, Monitoring and Evaluating Post-Disaster Recovery* (2008) by Daniel Brown, Stephen Platt and John Bevington were thoroughly studied.

With regards to methods in environmental assessment, *ISO 14001: 2004 Environmental Management Systems*; *Trash Track* by SENSEable City Lab; CASBEE (Comprehensive Assessment System for Built Environment Efficiency) manuals by The Japanese Sustainable Building Consortium and Institute for Building Environment and Energy Conservation; and *Guide to Green Building Rating Systems: Understanding LEED, Green Globes, Energy Star, the National Green Building Standard and More* (2010) by Linda Reeder were also reviewed and analysed.

The available literature in analysis and evaluation methods enabled an understanding of the importance, meaning and process of evaluation. No evidence was found to suggest any existing method that was dedicated to evaluating the functional performance of demountable buildings. However, this gap indicates even greater importance to developing a new evaluation method that can be directly used for demountable buildings.

1.8.2 Case Studies

Robert K. Yin states that there are four common types of case study design: single-case (holistic) designs, single-case (embedded) designs, multiple-case (holistic) designs, and multiple-case (embedded) designs.[105] A primary distinction when designing case studies is between *single*- and *multiple*-case designs. This means the need for a decision, prior to any data collection, on whether a single-case study or multiple-case studies are going to be used to address the research questions. The single-case design may be selected if: the case presents a critical test of existing theory, a rare or unique circumstance or a representative or typical case, or when the case serves a revelatory or longitudinal purpose. Any use of multiple-case designs should follow a replication, not a sampling logic, and an investigator must choose each case carefully. The fact that a design calls for multiple-case studies does not eliminate the variation identified earlier with single cases; each individual case may still be holistic or embedded. In other words, a

[105] Robert K. Yin, *Case study research : design and methods* (London: SAGE, 2009), 39.

multiple-case study may consist of multiple holistic cases or of multiple embedded cases. The individual cases within a multiple-case study design may be either holistic or embedded. An embedded case study methodology provides a means of integrating quantitative and qualitative methods into a single research study. The difference between these two variants depends on the type of research being studied and the research questions. In an embedded design, a study may require a survey to be conducted at each case study site.

In this research project, the main purpose for using a case study strategy was for the development of a conceptual model for evaluation that can be broadly adapted to all types of demountable buildings. Therefore, selecting a single case study as a unique case to present a new theory was not suitable, and only two case studies could present strong disagreement due to the difference between demountable buildings and transitional buildings. Having more than two case studies enables stronger and relatively objective conclusions. Furthermore, in this research, evaluating the functional performance of small-scale demountable buildings requires both quantitative and qualitative data from the designer, users and other stakeholders. The nature of multi-unit analysis, therefore, requires an embedded case study design instead of a holistic approach.

Upon the decision to use multi-case (embedded) designs, the author selected case studies from three companies to include in this research. These are: Chengdu Hualin Elementary School, designed by Shigeru Ban Architects from Japan in 2008; Exxopolis, designed by Architects of Air, a company based in Nottingham, UK, with twenty years of experience in designing and constructing inflatable structures; and Kreod, a multi-functional structure designed by young architect Chunqing Li, which was exhibited from 18 September 2012 and will be dismantled at the end of April 2013 for other exhibitions. These three case studies have been used as a research strategy to test the research hypothesis. They have been selected because of their accessibility, in terms of access to all of the designers for interviews; their appropriateness for the research topic (small-scale public demountable buildings); and because they were all built within the research period. The author analysed the case studies in terms of four aspects – function, finance, timescale and aesthetics – which are addressed in the second part of the literature review. After designing the Evaluation Conceptual Model, a questionnaire, including a description sheet and a ranking sheet, was sent to the designer of each case study for the evaluation of their projects. Concurrently, the author ranked the indicators of the model based on the data that had been collected through field research, interviews and questionnaires from the users' perspectives.

1.8.3 Fieldwork Research and Observations

The fieldwork research method involves the researcher being placed in direct personal contact with the social group being studying as they conduct about their affairs. Darin Weinberg states that fieldwork research is of benefit because "in contrast to interview techniques, wherein we ask people to tell us about their experiences and activities, observational fieldwork entails witnessing people's lives and circumstances first-hand".[106] In order to obtain a comprehensive understanding of the construction process of demountable buildings, the author visited a tents conference, Green & Away,[107] in July 2010 to observe the site, and participated in constructing tents to be used as toilets (including one for disabled users) at events. The main strategy was to work as a volunteer and be involved with the project coordinators and other volunteers, which enabled the author to gain first-hand experience of the project. A report of this observational fieldwork is available in Appendix A.

The author also observed places where demountable structures were frequently used, such as the Liverpool city centre area and Liverpool ONE[108], where small structures are often exhibited for seasonal markets and other commercial events. At other places, such as on the University of Liverpool campus, large-scale demountable structures have also been erected for a variety of events, such as exhibitions and graduation ceremonies.[109] Through observation and casual conversations with events participators, such as small festival tent owners and construction workers, the author was able to obtain a more

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[106] Darin Weinberg, *Qualitative Research Methods* (Malden, MA: Blackwell Publishers, 2002), 135.
[107] Green & Away is a charity and educational organisation providing outdoor conferences, exhibitions and workshops during the summer each year. The 2010 summer events were located in Bransford, Worcestershire.
[108] Liverpool ONE is a shopping, residential and leisure centre in Liverpool city centre, the creation of which involved the redevelopment of 170,000m^2 of under-utilised land. It was nominated for the RIBA Stirling Prize in 2009.
[109] According to Stephen Dunkley from the Safety Office, University of Liverpool, they have always used the *Safe Use and Operation of Marquees and Temporary Structures* guidance provided by MUTAmarq, a UK marquee hiring company as a minimum standard for the constructions of temporary structures on campus. They key contacts also include: Sian Winston (Head of Corporate Events), Clair Coombs (Business Development Manager) and Dave Hopkins (Strategy and Business Services). Clair Coombs is responsible of organising the 2013 summer Graduation marquee on Abercromby Square Gardens, which is a 50m x 15m marquee that goes up for Graduation week.

practical understanding of the common needs of demountable structures and why they are popular for public events.

1.8.4 Interviews

Conducting interviews as a research method has been widely used for qualitative approaches in social science research. Colin Robson distinguishes the different types of interview as the *fully-structured interview*, *semi-structured interview* and *unstructured interview*. He further identifies that a fully-structured interview has predetermined questions with fixed wording, and the use of a greater number of open-response questions is the only essential difference from an interview-based survey questionnaire. Unlike the structured interview, a semi-structured interview has guidance that serves as a checklist of topics to be covered, and a default wording and order for the questions, although the wording and order are often substantially modified based on the flow of the interview, with additional unplanned questions asked to follow up on what the interviewee has to say. Following a much more relaxed form, the unstructured interview has a general area of interest and concern, but allows the conversation to develop within this area and is often informal.[110]

In this research, the author has used all these three types of interview techniques. Two fully-structured interviews were conducted within this research: one was carried out on 4 December 2012 with Reiji Watabe, regarding the evaluation questionnaire for the Chengdu Hualin Elementary School case study. Another was organised on 17 December 2012 with Moshabab Aljarman, who worked as a supervisor engineer at the Mina Improved Tent Project in Mecca, Saudi Arabia in 1996, regarding the large-scale tents project and the identification of new features of how demountable structures can serve different purposes in comparison to transitional buildings.

The semi-structured interview was most widely used in this research, and in each case study, the author used this strategy to interview professional groups, including researchers, architects, designers, event organisers, construction organisers, volunteer students and users. In addition to case studies, the author also conducted semi-structured interviews to explore the wider field. Peter Lang was interviewed by the

[110] Colin Robson, *Real World Research : A Resource for Users of Social Research Methods in Applied Settings* (Chichester: Wiley, 2011), 279-80.

author on 10 April 2010 regarding Green & Away's annual tents conference and Professor Alfredo Brillembourg was interviewed via Skype on 1 October 2011 regarding UTT's (Urban Think Tank) Metro Cable Car project in Caracas, Venezuela in 2007 to 2010.[111] The author's intention was to identify how small-scale projects can be useful on a larger scale for wider audiences and users. The unstructured interviews were conversational in style, and were mainly used to access qualitative information from the demountable building/structure users that were identified through case studies.[112]

These three interview types have all proven to be valuable research techniques. The fully-structured interview was especially helpful in exploring the research context at an in-depth level. The semi-structured interview and unstructured interview were particularly beneficial in providing a flexible interviewing environment, thus enabling more free and open engagement with the interviewees. It should be noted that online communication platforms proved to be extremely helpful for long-distance collaborative research practice, with online social and communication platforms used for Skype interviews and focus groups.[113]

1.8.5 Questionnaires

The author administered questionnaires to participants identified through field research and case studies to obtain quantitative and qualitative data from the building/structure users. Research ethics approval to perform the questionnaires was granted by The University of Liverpool's Committee on Research Ethics. The project reviewers were Dr Carl Hopkins at the School of Architecture and Dr Richard Latto at the Institute of Psychology, Health and Society, University of Liverpool. The aim of the research is to design a less subjective, and more objective, evaluation method for demountable buildings. The purpose of the questionnaire was, therefore, to collect end users' opinions on different types of demountable buildings/structures. In general, three types of questionnaires were designed:

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[111] It should be noted that this interview was conducted to gain an in-depth view of the literature review and does not affect the research findings. Therefore, no interview sheet was attached in the Appendix. Some of the information which was gained from the interview could be useful for other researchers in the future; for example, on page 10, footnote 33, the author states that, according to the discussion during the interview, if any researcher wishes to contact Yona Friedman about an interview or meeting, the relevant fax number may be obtained by contacting Professor Alfredo Brillembourg.
[112] See Chapter 4 for the context of the unstructured interviews.
[113] This is discussed in detail in Section 1.8.6.

- Construction Participants Questionnaire – this was used to collect data from construction participants in order to understand how the deployment and dismantling process helped them to improve their skills. All the identified construction participants in this research were volunteers, and the details of these questionnaires can be found in Appendices A and C.

- User Questionnaire – this was a valuable means of data collection from users to assess the functional performance of the building/structure most directly. The details of related questionnaires and results can be read in Appendices C and D. Most of these questionnaires were sent to users as printed copies, and were stored in the Research Hub at the School of Architecture, University of Liverpool. However, during the visit to Exxopolis, designed by Architects of Air and displayed in Nottingham in June 2012, an iPad was also used for conducting questionnaire research. Application Survey Design – survey software integrating questionnaire designs with data input – was utilised, and enabled the author to identify new visitors to complete the questionnaires whilst attending to those visitor who had recently come out of the structure. This technique enabled the author to obtain as many results as possible, and also enabled direct engagement with visitors and the recording of their opinions through less formal conversations.

- Designer Questionnaire – this was designed at the final research stage, and used to test the Evaluation Conceptual Model. The questionnaires and additional instructions were emailed directly to the designers of the case studies, which allowed the author to draw research conclusions objectively and reflect fully on the research aim.

1.8.6 Group Discussions

The author arranged a Pecha Kucha[114] presentation with researchers, including the director Carlo Ratti[115] and the lab manager Gabriela Gomes from MIT SENSEable City Lab, on 4 September 2012. The purpose of this seven-minute presentation was to quickly explain the research findings to a group of senior researchers and propose an idea for how the work at SENSEable City Lab could be used in future research into demountable buildings. The author presented to the Lab because their research project, *Trash Track*,[116] is discussed in Chapter 3. The author argues that the Lab's sensing system technology could be used to track demountable building components in order to map their travelling lives. An interest was expressed in how these research findings and interests could be useful for future projects.

The purpose of arranging focus groups was to identify the research limitations and address further research questions through critical discussion. According to Tates et al., "online focus groups have considerable potential for gathering high quality data within a relatively short period of time from respondents who are unable or unwilling to engage in traditional group discussions".[117] Colin Robson agrees that conducting focus groups through the internet is becoming an increasingly popular method for collecting data.[118]

Summary

The research methodology in this thesis is an integration of both qualitative and quantitative techniques. Steven C. Currall and Annette J. Towler compared the characteristics of qualitative and quantitative methods in terms of realism, access to

[114] Pecha Kucha is a presentation methodology in which 20 slides are shown for 20 seconds each. This format keeps any presentation concise and fast. It was devised in February 2003 by Astrid Klein and Mark Dytham of Tokyo's Klein-Dytham Architecture as a method to attract people and allow young designers to meet up to share ideas and work.
[115] Carlo Ratti is an Italian architect and engineer who is also the director of MIT SENSEable City Lab. The lab is a world-leading centre that studies the built environment of cities using sensors and hand-held electronics that transform the way in which people understand cities. Ratti holds MPhil and PhD degrees in architecture from the University of Cambridge, UK.
[116] See Section 3.5.3.2 for further information.
[117] Marieke Zwaanswijk Kiek Tates, Roel Otten, Sandra van Dulmen, Peter M Hoogerbrugge, Willem A Kamps and Jozien M Bensing, "Online Focus Groups as A Tool to Collect Data in Hard-to-include Populations: Examples from Paediatric Oncology,"(2009), http://www.biomedcentral.com/1471-2288/9/15 (assessed 15 January 2013).
[118] Robson, *Real World Research : A Resource for Users of Social Research Methods in Applied Settings*: 298.

participants, detail, measurement precision, control, statistical conclusion validity and generalisability.[119] Based on their findings, the selected methods in this research can complement each other, and provide a relatively balanced research methodology frame for data analysis. The methods used were proven to be suitable and valuable throughout the research process when data was collected for analysis.

TABLE 1.3. Research methods conclusions[120]

		Literature reviews	***Non-participant observation***	***Field study (primary data)***	***Interviewing***	***Questionnaire***
Methods Used	***Realism***	Low	High	High	High	Low
	Access to participants	Low	Moderate	High	High	Moderate
	Detail	Moderate	High	Moderate	Moderate	Low
	Measurement precision	Low	Low	Moderate	Moderate	Moderate
	Control	Low	Low	Moderate	Low	Moderate
	Statistical conclusion validity	Low	Low	Low	Low	High
	Generalisability	High	Moderate	Low	Moderate	Moderate

1.9 Research Outline

There are five chapters in this thesis, which follow a step-by-step approach to explore and analyse the current research, before proposing a practical evaluation framework based on the study of existing research and testing it through realistic demountable building projects.

The objective of Chapter 2: Terms of Reference, is to review the current research relating to small-scale public demountable buildings and their evaluation. This chapter consists of three sections: (i) Definitions of the key terms used throughout the research. (ii) Analysis of the notion of small-scale buildings (presented through examining four key aspects: function, finance, timescale and aesthetics); and (iii) Analysis of two groups of selected demountable building projects and their relationships to the surrounding environment.

Chapter 3: Synthesis of Analysis and Evaluation Methods introduces the comparative evaluation and analysis methods that are currently in use, and investigates the

[119] Steven C. Currall and Annette J. Towler, "Status of Mixed Methods in the Health Sciences," In Abbas Tashakkori and Charles Teddlie, *Handbook of Mixed Methods in Social & Behavioral Research* (Thousand Oaks, Calif.: SAGE Publications, 2003).
[120] Ibid.

similarities and differences between them. It begins by discussing the role of evaluation in the demountable building design process, as well as the principles and the process of evaluation. Existing analysis and evaluation methods are introduced, based on thematic classifications that include General Methods, Assessment Methods in Humanitarian Response and Culture Development, and Methods in Environment Assessment. The final part of this chapter proposes an Evaluation Conceptual Model that addresses the important factors in the design, operation and use of demountable buildings.

The case studies from three companies are presented in Chapter 4: Case Studies, all of which have been used as a research strategy to test the research hypothesis. The case studies are Chengdu Hualin Elementary School, 2008, Exxopolis, 2010, and Kreod, 2012.

Chapter 5: Conclusions, the key findings of the thesis are draw together. It reflects on the theoretical aspects of the thesis and the empirical analysis made during the case studies. Finally, the limitations of the research are explored and directions for future research are proposed.

2

Terms of Reference

2.1 Introduction

This chapter reviews current research related to small-scale public demountable buildings. A list of relevant definitions are discussed including *demountable building*, *evaluation*, *functional performance*, *small-scale* and *public building* to establish the research scope. Key factors in the design and operation of public, demountable buildings are identified to create the research context.

In section 2.4, a series of large demountable building projects have been analysed to ascertain the relationships between public demountable buildings and sites for two reasons: To overview the interconnection between buildings and their sites; and because most large demountable building projects are designed by world renowned architects, engineers and designers with rich experience in architectural design. As such, their projects are representative of the building design industry and can have a deep and wide influence in the future design of demountable buildings.

This chapter consists of three parts: (i) Definitions of the key terms used throughout the research. (ii) Analysis of the notion of small-scale buildings, (presented through examining four key aspects; function, finance, timescale and aesthetics), and (iii) analysis of two groups of selected demountable building projects and their relationships to the surrounding environment.

2.2 List of Definitions

This section identifies the key definitions that have been addressed in the thesis including *demountable building*, *evaluation*, *functional performance*, *small-scale* and *public buildings*. These definitions will clarify the scope of the research.

2.2.1 Demountable Buildings

Robert Kronenburg defines demountable buildings as:

> Those that are transported in a number of parts for assembly on site. They are much more flexible in size and layout and can usually be transported in a relatively compact space. They have some of the limitations that site operations bring to a conventional building and, depending on the size, complexity, and ingenuity of the system, are not as instantly available.[1]

Similar to demountable buildings, demountable structures are often used for public events. These structures include: temporary seats, shelters, media facilities and stages. The Institution of Structural Engineers identifies the definition of *temporary demountable structures* as:

> Structures which are in place for a short time, generally no more than 28 days, that are designed to be erected and dismantled manually many times. They are usually made from lightweight components and are used for a wide variety of functions at public and private events. They include grandstands, tents and marquees which may accommodate large numbers of people, and stages and supports for performers.[2]

Historically there has been a demand for the construction of demountable buildings and structures. To summarise the key aspects of demountable structure, P.S. Westbury states that:

> A demountable structure must provide flexibility to the end user. The system must be capable of being transported within a minimum number of standard size units, it must be quick and easy to erect and dismantle, it

[1] Kronenburg, *Houses in Motion*: 10.

[2] Institution of Structural Engineers, *Temporary Demountable Structures : Guidance on Procurement, Design and Use* (London: Institution of Structural Engineers, 2007), xii.

> must involve as few dedicated site personnel as possible and it must be deployable on any realistic site.[3]

The boundary between demountable buildings and structures becomes blurred when structures can provide the same functional use as a building. It is important, however, to identify whether a project is a building or functional structure when construction law needs to be addressed for installation and deconstruction guidance.

2.2.2 Evaluation

In the *Guidelines for Operational Programme Formulation in Post-disaster Situations*, developed by UN-Habitat Risk and Disaster Management Unit, evaluation is defined as: "a process that seeks to determine as systematically and objectively as possible the relevance, effectiveness and impact of activities carried out with regard to their objectives."[4] In order to make the definition clear, UNCHS (The United Nations Centre for Human Settlements) explains the differences between evaluation and monitoring. It states:

> Evaluations tend to place value on the achievements of a project, while monitoring is usually not judgement based. Evaluations are therefore more selective and are geared to determine specific criteria–relevance, success and performance of the project.[5]

In the ISO (International Organization for Standardization) online data base[6], there are many different definitions for evaluation, with a selected list of relevant definitions in Table 2.1:

[3] P.S. Westbury, "Demountable Building-A New Design Strategy?" In Mobile International Conference on et al., "Mobile and Rapidly Assembled Structures II : Second International Conference on Mobile and Rapidly Assembled Structures, MARAS 96" (Ashurst, Southampton; Billerica, MA, 1996), 420.
[4] UNCHS Risk and Unit Disaster Management, *Guidelines for Operational Programme Formulation in Post Disaster Situations : A Resource Guide* (Nairobi, Kenya: UNCHS (HABITAT), 2001), 92.
[5] The United Nations Centre for Human Settlements (UNCHS) Habitat and Risk and Disaster Management Unit, *Guidelines for the Evaluation of Post Disaster Programmes : A Resource Guide* (Nairobi, Kenya: UNCHS (HABITAT), 2001), 14.
[6] ISO (International Organization for Standardization) is the world's largest developer and publisher of International Standards. It is a non-governmental organization that aims to connect between the public and private sectors. The ISO Online Browsing Platform provides users with easy access to graphical symbols, codes or terms and definitions. It allows users to access the most recent content, run full-text searches and preview content before purchasing any standard.

TABLE 2.1. Selected definitions of 'evaluation' from ISO Concept Database (2010-10-11)[7]

Identifier	Reference	Title	Edition	Committee	Definition
CDB-00175769-001	ISO 14044:2006	Environmental management-Life cycle assessment-Requirements and guidelines	1	ISO/TC 207/SC 5	Element within the life cycle interpretation phase intended to establish confidence in the results of the life cycle assessment
CDB-00177886-001	ISO 16813:2006	Building environment design-Indoor environment-General principles	1	ISO/TC 205	Sub-process to assess the proposed design with regard to the design criteria at each of the design stages
CDB-00175112-001	ISO 14040:2006	Environmental management-Life cycle assessment-Principles and framework	2	ISO/TC 207/SC 5	Evaluation includes completeness check, sensitivity check, consistency check, and any other validation that may be required according to the goal and scope definition of the study
CDB-00196377-001	ISO/PAS 22539:2007	User guidance to ISO 15928-House-Description of performance	1	ISO/TC 59.SC 15	Confirmation that the nominated performance is achieved

The OECD/DAC (Organisation for Economic Co-operation and Development/The Development Assistance Committee) highlights four key points relating to evaluation:

> It is a systematic and objective assessment of a project (either ongoing or completed); it assesses the project design, implementation and results; the goal is to determine the project's relevance, achievement of objectives, efficiency, effectiveness, impact and sustainability; it should provide credible, useful information that will enable the lessons learned from the project to be incorporated into the programme or project.[8]

Yehuda E.Kalay defines the meaning of evaluation as "a direct consequence and derivative of the uncertainty that is inherent to the process of design",[9] further stating

[7] ISO (International Organization for Standardization), "The ISO Concept Database."; ibid.
[8] The United Nations Centre for Human Settlements (UNCHS) Habitat and Unit, *Guidelines for the Evaluation of Post Disaster Programmes : A Resource Guide*: 13.
[9] Yehuda E. Kalay, *Architecture's New Media : Principles, Theories, and Methods of Computer-Aided Design* (Cambridge, Mass.: MIT Press, 2004), 295.

that “the process that performs such predictions and comparisons and determines if the solutions meet the goals and abide by the constraints.”[10]

Bernhard Tschumi[11] was invited to a Public Debate event at ETH Zürich with Rem Koolhaas[12] on 18 May, 2011. His opinion on the use of evaluation was that an evaluation system is used to create a series of scenarios in order to understand what architecture is and how it can be designed differently.[13] This thesis argues that evaluation methods for small-scale public demountable buildings can be varied and optional, with the key point being that the selected method(s) reflects the architect or designer’s design intention from a specific aspect. As such, the meaning of evaluation can be discussed logically and the possible evaluation methods can be quantified. Consequently, in this thesis, evaluation means establishing a set of relevant criteria for evaluation to enable project operators to begin to address functional performance from a public perspective and reflect on the scope of their projects.

2.2.3 Functional Performance

Volker H. Hartkopf[14], Vivian E. Loftness[15], and Peter A. D. Mill[16] argues that it is important to identify a complete definition of building performance mandates to be met by building policy makers, programmers, architects, engineers, contractors, owners, and managers, in order to understand the meaning of functional performance.[17] The performance of a building reflects on the performance of its function, and there are six performance criteria in building performance evaluation: building integrity, thermal comfort, acoustic comfort, visual comfort, air quality and spatial comfort. Any problems

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[10] Ibid.

[11] Bernhard Tschumi was born in Switzerland in 1944. He is an architect, writer and educator, educated in Paris and ETH in Zürich.

[12] Remment Lucas Koolhaas was born in 1944 in Rotterdam, Netherlands. He is an architect, theorist and educator and the founding partner of OMA (Office for Metropolitan Architecture), an architecture firm based in Rotterdam. Rem Koolhaas won the Pritzker Architecture Prize in 2000.

[13] Rem Koolhaas; Bernhard Tschumi; Stephan Trüby, "A Conversation," (ETH Zurich, Switzerland: ETH Zurich, ITS-MMS; Switzerland, 2011).

[14] Associate Professor, Department of Architecture, Carnegie-Mellon University, United States.

[15] Adjunct Associate Professor, Department of Architecture, Carnegie-Mellon University, United States.

[16] Director, Architectural and Building Science, Public Works Canada, Ottawa, Canada.

[17] Volker H. Hartkopf, Vivian E. Loftness, and Peter A. D. Mill, "The Concept of Total Building Performance and Building Diagnostics" In Gerald Davis and Astm Committee E-6 on Performance of Building Constructions, *Building Performance : Function, Preservation, and Rehabilitation : A Symposium Sponsored by ASTM Committee E-6 on Performance of Building Constructions, Bal Harbour, FL, 17 Oct. 1983* (Philadelphia, PA: ASTM), 6.

arising from these six performance criteria will affect users to varying degrees and, therefore, the functional performance of the building.[18]

TABLE 2.2. Building Performance Mandates, Adapted from Volker H. Hartkopf, Vivian E. Loftness, and Peter A. D. Mill[19]

BUILDING PERFORMANCE MANDATES

Building Integrity	***Thermal Comfort***	***Acoustic Comfort***	***Visual Comfort***	***Air Quality***	***Spatial Comfort***
moisture: rain, snow, ice, vapour	air temperature	sound pressure level and frequency	ambient and task levels: artificial and daylight	ventilation rate: fresh air supply, circulation,	work station layout
temperature	radiant temperature	reverberation and absorption	contrast, brightness ratios,	mass pollution	work group layout
air movement	humidity	speech privacy, articulation index	colour rendition	energy pollution	conveniences, services
radiation and light	air speed	vibration	occupancy factors and controls	occupancy factors and controls	amenities
chemical attack	occupancy factors and controls	occupancy factors and controls			occupancy factors and controls
biological attack					
fire safety disaster					

The building comfort criteria are generally affected by temperature, humidity, outdoor air supply, filter selection, visual criteria and noise, alongside other factors potentially affecting comfort, such as temperature variations, colour of surfaces and lights and the age, gender and health of users.[20]

For a small-scale public demountable building, the typical development team includes:

- **Clients:** owner of the project, main funding body
- **Designers:** including architects, designers and artists who are involved in designing the development in accordance with all relevant constraints (including site, costs, regulations, market intelligence)
- **Developers:** monitor the project and manages it through to completion.
- **Planning consultants:** advises on acceptability to local planning authorities and negotiates with planning authorities in cases where planning consent is

[18] Volker H. Hartkopf, Vivian E. Loftness, and Peter A. D. Mill, "The Concept of Total Building Performance and Building Diagostics" In ibid.
[19] Volker H. Hartkopf, Vivian E. Loftness, and Peter A. D. Mill, "The Concept of Total Building Performance and Building Diagostics" In ibid., 7.
[20] Michael Humphreys and Fergus Nicol, "Environmental Criteria for Design" In Engineers Chartered Institution of Building Services, *Environmental Design : CIBSE Guide A* (London: CIBSE, 2006), 8-9.

controversial.[21]

The above groups consist of professionals who participate together to deliver projects to public visitors, the end-users of the building. Depending on the project scale and complexity, each role within the development team may be flexible, for example; designers may also take part in the developers' or planning consultants' work. Designers are at the core of the team because they are charged with responding to all other parties during the design process, construction process and dismantling process, to make sure the design brief is achieved.

Andrew C. Lermer and Fred Moavenzadeh, as cited in Hartkopf, Loftness, and Mill (1983), suggest that: "When evaluating such a system of building and community, performance can be stated and alternatives compared in terms of suitability, reliability, and flexibility."[22] They further explain:

> *Suitability* is a measure of the degree to which a building and its component parts serve user needs in the present and near future. Reliability is expressed as the probability that the service will continue to perform as intended through the life of the facility, given appropriate maintenance and use. *Flexibility*, including adaptability, is a measure of the system's ability to accommodate changing functions and occupancies and the continuing effort and resources required during the building life cycle to maintain suitability.[23]

Steen Eiler Rasmussen writes: "The building should be experienced in function."[24] The author concludes that, in this thesis, functional performance means the satisfaction levels of operating the events, planning the project, monitoring the construction and dismantling process, communicating with the local authorities, visiting the buildings and participating in the activities. The functional performance of small-scale public demountable buildings can also be evaluated based on suitability, reliability and flexibility. Suitability measures the degree to which a demountable building serves the users' (clients and visitors) needs, reliability measures the continued quality of a

[21] William Fawcett, Ian Ellingham, and Stephen Platt, "Reconciling the Architectural Preferences of Architects and the Public," *Environment and Behavior* 40, no. 5 (2008): 601.
[22] Andrew. C. Lermer and Fred. Moavenzadeh, "Performance of Systems of Constructed Facilities," In Bruce E. Foster et al., *Performance Concept in Buildings; Proceedings of a Symposium* (Washington: U.S. National Bureau of Standards; for sale by the Supt. of Docs., U.S. Govt. Print. Off., 1972).
[23] Volker H. Hartkopf, Vivian E. Loftness, and Peter A. D. Mill, "The Concept of Total Building Performance and Building Diagnostics," In Davis and Constructions, *Building Performance : Function, Preservation, and Rehabilitation : A Symposium Sponsored by ASTM Committee E-6 on Performance of Building Constructions, Bal Harbour, FL, 17 Oct. 1983*: 8.
[24] Steen Eiler Rasmussen, *Experiencing Architecture* (Cambridge [Mass.: M.I.T. Press, Massachusetts Institute of Technology, 1962), 158.

building throughout its lifespan, and flexibility focuses on the design and measures whether it serves multi-functional purposes and can be adapted to other projects. Only by assessing the functional performance will clients discover the operational efficiency, designers discover the planning efficiency, developers discover the construction efficiency, planning consultants discover the acceptability by the users and appropriateness at the building site, and the users discover the functional efficiency.

2.2.4 Small-scale

Small-scale projects are not intended to solve large, systemic problems by applying abstract concepts or complicated theories. Instead, they identify a specific need and set out to meet it satisfactorily and efficiently. The characteristics of small-scale projects in this thesis are defined as those listed below.

A tool for users to customise buildings - every building has secondary aspects of customisation, and due to the small size, customised areas can be seen in small-scale projects.

Adaptability in structure - once small-scale demountable buildings are dismantled, they can be adapted into medium or large-scale buildings. For example, when using ISO standard containers as temporary building solutions, the containers can be organised into many different arrangements according to the requirements.

Architectural design education - many small-scale demountable buildings do not require cutting-edge technology. They can be assembled by builders, non-professional volunteers and students. These involved in these projects can experience first-hand the construction process and participate in the deployment of a building or structure back into small components. This can enhance the understanding of architectural design, and can, therefore, assist with young architects or designers to establish their early career.

Commercial benefits - the appearance of a small-scale demountable building often easily catches visitor attention. Many visitors can be attracted by the flexible form of the building as well as by the events and exhibitions within it. In addition, the building can attract attention from the local press and media due to its ‘unusual’ style, and these advantages can lead the project to become a commercial success for the clients and create opportunities for future funding for the designers.

Encourages design innovation - small-scale demountable buildings can be quickly deployed and dismantled in a relatively short time. Consequently, they strongly encourage design innovation by providing novel opportunities for design and industry. Small-scale projects can be used as design experiments to test designs for larger projects.

Flexible in function - small-scale demountable buildings have the ability to respond quickly to challenges. They can be adapted according to the architectural briefing to meet individual needs in a relatively short time.

Individuality – a completed small-scale project can offer the satisfaction of producing something that is all one's own. Each small project can be unique, which is ideal for architects and their clients who want to stand out in order to compete with others.

Lightness - small-scale projects are not only defined by scale but also by lightness. Lightness does not always mean light in weight but also means light in appearance. Steen Eiler Rasmussen[25] writes: "as a building can be made to appear heavier than it actually is, it can also be made to appear lighter than it is."[26] This characteristic is particularly beneficial to users when small-scale buildings are used to produce a relaxed 'light' atmosphere for disaster relief projects.

Low budget - small-scale demountable buildings usually have minimal requirements for materials, construction tools and construction areas. They are, therefore, often a cost effective solution.

Low risk - small-scale projects require a low budget and small working team. Project developers are more likely to take the relatively smaller risks in project completion (in terms of time management, availability of material resources, health and safety issues and security), than those of larger budget projects.

Native construction material requirements - it is the nature of many small-scale projects that most of the construction materials can be accessed locally. Consequently,

[25] Steen Eiler Rasmussen (1898-1990). He was a Danish architect and urban planner who was a professor at the Royal Danish Academy of Fine Arts.
[26] Rasmussen, *Experiencing Architecture*: 91.

the meaning of “small” in this thesis also refers to the majority of the construction materials being supplied locally.

Short construction and dismantling time - large building projects can take years, decades or even centuries to be completed. The construction of demountable buildings can be completed within a short time, (months, days, even hours), according to requirements. They can also be dismantled quickly and easily.

Simplicity – an important characteristic of a small-scale project is its simplicity. It can either be simple of structure or of function. Architects and designers can maintain control of their projects by avoiding unnecessary complexity.

Small building site - small-scale demountable building projects require very limited building site areas compared to medium or large-scale projects. It is, therefore, easier to find a suitable site and seek permission for construction if the projects are to be built on-site.

Small working team - small-scale projects do not depend on the assembly and management of a large professional team. Volunteers, students or non-professional temporary employees can complete them to a high standard after being provided with a general understanding of necessary construction skills.

2.2.5 Public Buildings

In book *Beyond Public Architecture: Strategies for Design Evaluation* (1990) Hamid Shirvani states that; “public architecture is those public spaces and places which constitute the non-private side of a building and its landscape and their common grounds.”[27] According to *The Promotion of the Use of Energy from Renewable Sources Regulations 2011*: “‘public building’ means a building owned by a person or body with functions of a public nature.”[28] A ‘public building’ embodies the concept of being suitable for a broad audience rather than for an individual. It also embodies the idea of being capable to communicate with its audience through its design. Public buildings can

[27] Hamid Shirvani, *Beyond Public Architecture : Strategies for Design Evaluations* (New York: Van Nostrand Reinhold, 1990), ix.
[28] "The Promotion of the Use of Energy from Renewable Sources Regulations 2011," (2011), http://www.legislation.gov.uk/uksi/2011/243/pdfs/uksi_20110243_en.pdf.

be either commercial or non-commercial, depending on the design objectives, and small-scale public demountable buildings can be built in either public space or private space according to the clients' requirements.

Matthew Carmona et al identify that the relative 'publicness' of space can be considered in terms of three qualities: *ownership*, *access* and *use*. The term 'ownership' stands for whether the space is publicly or privately owned. The term 'access' refers to whether the space has public access to it, and this poses the question of whether a place becomes private when an admission fee is charged. For example, if a museum (an art gallery) changes an entry fee, another does not, is the former public and the latter not, or are neither truly public? Whilst, in urban design terms, 'accessibility' is the capacity to enter and use a space, not all public spaces are 'open' and accessible to everyone and the term 'use' refers instead to whether the space is actively used and shared by different individuals and groups. [29]

In this thesis, the term 'public buildings' has two meanings: buildings for the general public including disabled people and people with special requirements; and buildings for a group of people with shared interests or activities.

2.2.6 Summary

Shirvani writes that: "there are four basic approaches to public architecture design evaluation: discretionary, flexible, design option and self-administering." [30] A discretionary approach means that the design evaluation team have the control of evaluation standards and criteria to the extent that they can determine which method they will use for the evaluation process. A flexible approach is a guideline that provides a general architectural design framework without specific solutions. This guideline is normally provided by the project developer. Consequently, the evaluation team of review body can work within the established parameters, but they can use discretion in different projects. A design option approach means that the evaluation team has a responsibility to check if the chosen evaluation method is suitable for the guideline

[29] Matthew Carmona et al., *Public Places Urban Spaces : The Dimensions of Urban Design* (Oxford: Architectural Press, 2010), 137.
[30] Thomas Nally, *Design Review, Alternative Models of Administration* (M.Arch.A.S./M.C.P. thesis, MIT, 1977); Hamid Shirvani, *Urban Design Review* (Chicago: Planners Press, 1981), quoted in Hamid Shirvani, *Beyond Public Architecture : Strategies for Design Evaluations*: 59.

(flexible approach). A self-administering approach suggests using a number of informal evaluation procedures rather than a formal evaluation process. This would enable practitioners to work creatively in an otherwise restrictive process. These four approaches might not apply to complex building projects or informal buildings, but they can be considered as references for the next stage of the research.

2.3 Key Factors in the Design and Operation of Public Demountable Buildings

Stephen A. Brown states, in his book *Communication in the Design Process* (2001) that the four subdivisions of architecture briefing are *function*, *finance*, *timescale* and *aesthetics*.[31] This basic frame has been adapted here to small-scale public demountable buildings in order to analyse their design and operation.

2.3.1 Function

Yona Friedman writes: “The style of a building consists in its users. An unused building is nothing else than a ruin.”[32] He states in his essay ‘Function Follows Form’; “function, for architects, is a mechanistic concept; how should a building be used? The function of each architectural space is determined, first of all by the equipment specific for that space: furniture and fixture.”[33]

[31] Stephen A. Brown, *Communication in the Design Process* (London; New York: Spon Press, 2001), 32.
[32] Yona Friedman, "Function Follows Form," In Jonathan Hughes and Simon Sadler, *Non-plan : Essays on Freedom Participation and Change in Modern Architecture and Urbanism* (Oxford; Boston: Architectural Press, 2000), 111.
[33] Ibid., 104.

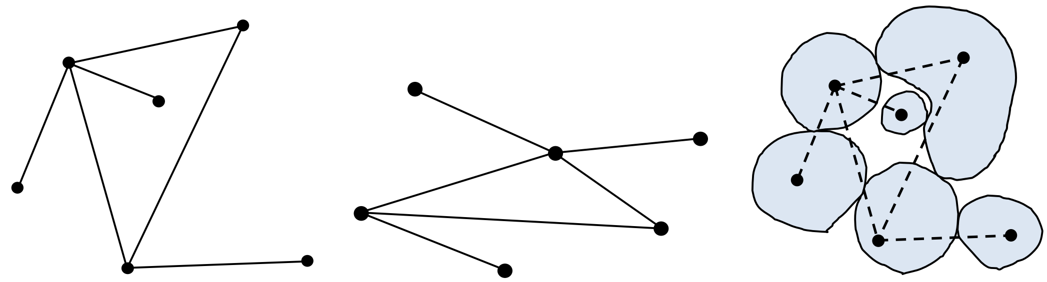

FIGURE 2.1. - 2.3. Linkage scheme; Topologic Transformation of a linkage scheme; The dual of the linkage scheme[34]

Friedman further argues that for architects, the functional points can be understood as points in a linkage scheme. Graphs can be used for mapping a linkage scheme, with nodes representing specialised equipment and lines being the paths to link these specialised spaces (Figure. 2.1.).[35] He explains that a graph is a topological figure which has no definite form and which can take many different patterns (Figure. 2.2.).[36] Friedman concludes that function can follow any form when it is mapped by a graph (Figure 2.3.).[37]

Friedman's ideas lie mainly in theory, while the question must be what is it like in the reality? At the Transsolar KlimaEngineering Symposium in Germany 29 June, 2012, Alfredo Brillembourg argued that "function sometimes doesn't follow form".[38] His opinion is that the social aspects of design do not always follow form because the designer cannot see the totality of the system and they should act on local knowledge contextualised with interdisciplinary perspectives.[39]

Alan R. G. Isaac concludes that:

> The functional aspect of the environment for human activity will involve the provision of shelter; privacy; arrangement of the contents for a particular purpose; activity control visually and physically; the removal of adverse conditions, such as noise, cold, heat and technical considerations involved in the provision and control of natural and artificial conditions.[40]

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[34] Yona Friedman, "Linkage Scheme; Topologic Transformation of a Linkage Scheme; The Dual of the Linkage Scheme," (Oxford; Boston: Architectural Press, 2000), 105.
[35] Yona Friedman, "Function Follows Form," In Hughes and Sadler, *Non-plan : Essays on Freedom Participation and Change in Modern Architecture and Urbanism*: 105.
[36] Ibid.
[37] Ibid.
[38] Alfredo Brillembourg, "Emerging Cities," (21 September2012).
[39] Ibid.
[40] Alan R. G. Isaac, *Approach to Architectural Design* (London: Iliffe Books, 1971), 70.

The author argues that in small-scale public demountable buildings, the most commonly examined aspects by architects and designers when they design for function are *spatial comfort* and *usability*.

2.3.1.1 Spatial Comfort

Similar to other building types, the consideration of spatial comfort in small-scale public demountable buildings, is linked with anthropometrics, ergonomics, ability and disability, circulation spaces, activities, furniture arrangements and storage considerations. Anthropometrics concerns the study of human body measurements, i.e. the measurement of 'users', and this plays an important part in small-scale public demountable building design because the available space is normally limited in size.

Ergonomics concerns the qualities of the design of the spaces and equipment, based on anthropometric data, to provide: comfort, safety, ease of use and efficiency for visitors and workers. It concerns the relationships between the user, equipment for the activities and the building. The ergonomic disciplines for static public buildings can also be used and referenced for demountable buildings.

According to the statistics from The Office for Disability Issues in Great Britain there are over 10 million people with a limiting long-term illness, impairment or disability, and the most commonly reported impairments are those that affect mobility, lifting or carrying.[41] Whilst some disabled people may use wheelchairs and crutches for moving and walking, there are also people who are not disabled but need special care regarding space in public buildings, such as pregnant women and parents with pushchairs or small children. In small-scale demountable buildings, the design of circulation space is important because it often includes paths to emergency exits. According to the specific project and activities, the requirements for the furniture position/style arrangements and storage considerations are different, but based on the same measurements utilised for static buildings.

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[41] Office for Disability Issues HM Government, "Disability Facts and Figures, An Overview of Official UK Disability Statistics from the Ofice for Disability Issues," The Office for Disability Issues, http://odi.dwp.gov.uk/disability-statistics-and-research/disability-facts-and-figures.php#ls.

2.3.1.2 Usability

Usability has been defined by ISO in terms of certain products. It is stated in Annex A, *(Informative) Concept of Functionality and Serviceability* in ISO 11863:2011 (Building and Building-Related Facilities - Functional and User Requirements and Performance - Tools for Assessment and Comparison) as "A product of manufacture, made in quantities of identical products, such as a computer terminal, should meet the functional requirements of its users."[42] The term "usability" is defined in ISO 9241-11:1988 as the; "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."[43] Usability also depends on software functional qualities[44] which contribute to the quality of the work system in use. Usability needs to be focussed on as the real purpose of the design of a product, and which meets the needs of real users in their specific environment.[45] According to Annex D of ISO 9241-11:1988, the usability of a product could be measured by analysis of the features of the product and the process of interaction with the product, by analysing the effectiveness and efficiency from the use of product and the satisfaction of the users.[46] The question is, therefore, whether the definition of usability and the methods of measuring usability in the context of manufactured products can be also applied to buildings in general and more specifically to demountable buildings.

As stated in Annex A of ISO 11863:2011: "If buildings are also considered as tools or aids to users, then the concept of usability also applies, though unlike manufactured products, each building or building-related facility is unique at least in its physical location and typically in many other features as well."[47] In reference to small-scale demountable buildings therefore, usability is: how convenient it is for the clients to host

[42] ISO 9241-11:1988, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)-Part 11: Guidance on Suability, quoted in International Standards Office, "ISO 11863:2011 (E), Building and Building-Related Facilities - Functional and User Requirements and Performance - Tools for Assessment and Comparison," (Geneva2011), 12.
[43] Ibid.
[44] In business context, software quality refers to software functional quality and software structural quality. Software functional quality reflects how well it complies with or conforms to a given design, based on functional requirements or specifications. Software structural quality refers to how it meets non-functional requirements that support the delivery of the functional requirements, such as robustness or maintainability.
[45] International Standards Office, "ISO 11863:2011 (E), Building and Building-Related Facilities - Functional and User Requirements and Performance - Tools for Assessment and Comparison."
[46] Ibid.
[47] Ibid.

activities inside the buildings and how easy it is for the building users to participate in these activities.

Usability can be measured; the purpose of which is to obtain feedback from the users for architects, designers and stakeholders for further evaluation. The usability of a demountable building is often measured by analysing the efficiency of users' navigation by way of observation, interviews and surveys. This method of performing usability measurement relies heavily on qualitative analysis which includes formal and informal interviews in person, by telephone or via the internet.

2.3.2 Finance

Ezra D. Ehrenkrantz writes: "the cost of buildings should be dealt with at three different levels: *i* the cost of the building proper, *ii* the cost to build the physical plant, *iii* the cost to allocate for space, environment, services and finishes."[48] When evaluating the functional performance of a demountable building, it is essential to consider all costs incurred during its lifetime. In demountable buildings, the 'cost of the building proper' includes construction materials, components, building machinery and tools. The 'cost of physical plant' includes the hiring of construction workers, design service, operation and the transportation of building elements or components. The 'cost for allocation' includes: renting or occupying the building site (indoor or outdoor), administrative services and allocating waste building materials. In addition to these three levels, costs of demountable buildings include those of dismantling the building and storing and transporting its components for future use. Demountable buildings can be dismantled and reconstructed quickly and economically. Demountable components can, however, cost more than fixed components because of the additional cost of acquiring a design which is flexible and adaptable, and the additional cost of their specialist manufacture.

Generally, the scale of a demountable building is a key aspect in controlling its finance. For example, a smaller scale building will require less material and should therefore, cost less. Further ways to help reduce costs include re-using the building elements, and a key characteristic of a demountable building is that most of its components can be dismantled and re-constructed in whole or in part. If they have been well maintained

[48] Ezra D. Ehrenkrantz, *Architectural Systems : A Needs, Resources, and Design Approach* (New York: McGraw-Hill, 1989), 65.

the elements that make up the components can be re-used many times rather than being abandoned or recycled.

An efficient method of cost reduction is the use of local materials to reduce material transportation costs. Shigeru Ban's Nomadic Museum, which was constructed from steel shipping containers and paper tubes travelled from New York to Santa Monica and then to Tokyo, but each building site, the majority of the containers used were from the local area. Only small numbers of containers were retained for the transportation of other construction materials such as paper tubes. The containers used for transportation were then reused as construction elements.[49] A further possible method of cost reduction is to apply multiple functions to limited space, for example, circulation space can also be used as exhibition areas or reception.

Whole-life costing is a useful tool for estimating the best cost option for the life of a building and, according to William Fawcett, is used as an essential foundation for sustainable design. It means that when comparing alternative strategies for constructing a project, the cheapest appearing alternative may not be the most economical in the long term. Whole-life costing can often show that a durable and efficient building, despite higher construction costs, is better value and more sustainable in the long-term than a more cheaply built design with high running costs.[50]

Reducing building costs alone does not necessarily make a building economically sustainable. If a demountable building has been built for commercial purposes, it may offer faster payback and commercial benefits for the project owners by comparison with static buildings. If there is insufficient payback or commercial benefits, the building can be considered to be unsuccessful. It is argued here that 'finance management' not only refers to reduction (materials costs, transporting and construction time), but also to growth. Growth includes improving the quality of the buildings' functions and usability, and improving quality of life, for example by engaging with the local community. Growth can also mean creating increased opportunities for commercial benefits for future projects.

[49] Shigeru Ban et al., *Shigeru Ban : Paper in Architecture* (New York: Rizzoli, 2009), 192.
[50] William Fawcett, "Whole-life Costing," http://www.carltd.com/wholelife.htm.

2.3.3 Timescale

Timescale is the duration of the project, and in this thesis, it includes: design, construction, use (by events operators and visitors), deployment and transportation.

Design - small-scale, public, demountable buildings can be designed in a relatively short time, especially when the design does not rely on high-technology. Depending on the complexity, the time for design is not always short, for example, it took five years for the first Soundforms (see page 70) prototype to be delivered from its inception. In other projects, such as Shigeru Ban's paper architecture, the specific building can be designed quickly by the architecture team and constructed rapidly by volunteer students, but this is following many years of prior experience. For example, Ban has almost 30 years of experience in using paper as a construction material and is familiar with the techniques, and it can be argued, therefore, that a good demountable building design is not to be measured by the length of design time but should rather be measured through its form, function and structure.

Construction - depending on the availability of materials and the construction team, small-scale public demountable buildings can be built in a short time, ranging from less than half an hour to one month.

Use - unlike residential demountable buildings, public demountable buildings are often used for a short time, often during the daytime, but sometimes in the evenings for special occasions such as live music or concerts.

Deployment - the fundamental premise for a demountable building is the breaking down of a building into its individual elements so that it can be transported from one building site to another, or to a storage place. The speed of deployment can be faster than construction, and if the building is to be reused without any changes to its design or if the components can be transported whole, it is often not necessary to dismantle the building completely.

Transportation - chosen transportation methods may restrict the unit size of building elements, as permitted transport dimensions may not be exceeded. It is imperative that the building elements be properly secured during transport and protected against possible damage en-route. Normally, individual units are combined to produce appropriate transport loads, and high-quality building elements are often transported in steel containers, in which they are particularly well-protected. For long-distance deliveries, rail and sea transport are economical solutions with the last stage of delivery to site is generally made by truck/van. Delivery by air is usually only practical for extremely inaccessible sites due to high cost and weight restrictions.

Some demountable buildings will be completely reconstructed following redeployment, and others will be partly re-used and some will be entirely recycled. Through the study of existing projects, this thesis analyses the entire life cycle of a demountable building within the three scenarios (Figure. 2.4.):

(i) All building elements will be re-used - following use, and according to specific needs, some demountable buildings are immediately redeployed and some will be transported for temporary storage before being used or exhibited again. The difference is that the buildings which require storage incur additional transportation time and costs compared to those which are directly transported to the next building site.

(ii) A quantity of building elements will be re-used - in some circumstances, it is not necessary to re-use the entire building, for example, where clients expect new designs, or if it is more cost-effective for stakeholders to recycle some building parts. It is also possible that some building elements cannot be re-used due to damage or because they are made from low-quality materials which will not withstand a further use. In these cases, some elements are abandoned by the project directors at the end of the deployment.

(iii) All building elements will be recycled - sometimes, it is most efficient to recycle the entire building, particularly when the first design is not considered successful or where the project owner does not need to keep the design. Budgetary reasons or transportation limitations can also affect this decision.

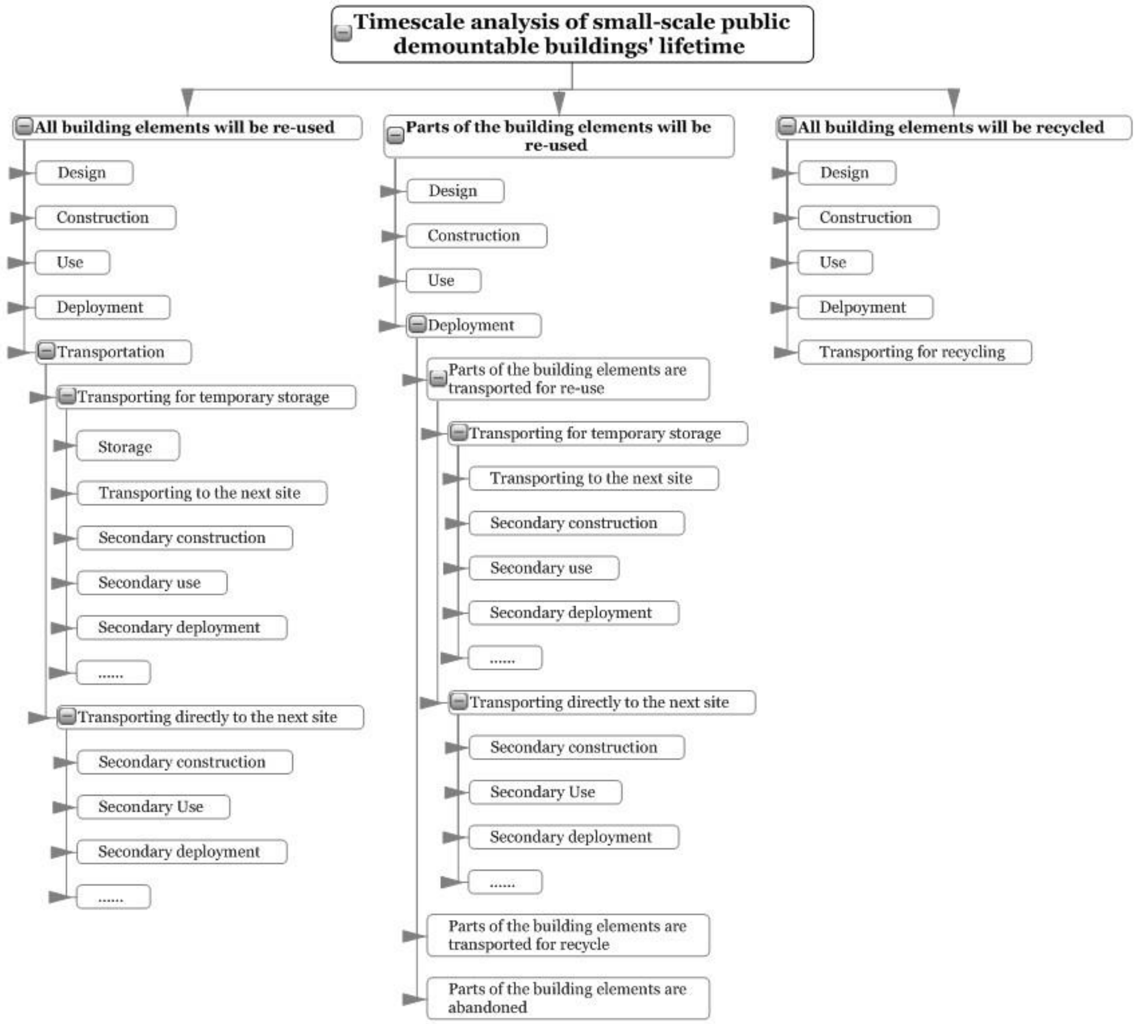

FIGURE 2.4. Timescale analysis of small-scale public demountable building's lifetime

A timescale and clear objectives are normally established and agreed during the architectural briefing process. Herein the project overview needs to be broken down into manageable tasks. This helps to classify the tasks required and identify the relationships between each work package before establishing what will be required to complete each task. Risk and uncertainty may also be revealed during this process. Gantt Chart, Microsoft Excel and Network Analysis Software such as Mind Genius (used for Figure 2.5.) can be used to aid architects and project managers to schedule realistic tasks in order to achieve the design objectives.

2.3.4 Aesthetics

Aesthetics is defined by Michael Kelly as "critical reflection on art, culture and nature."[51] In architecture, aesthetics generally means appearance and sense, referring to matters of visual quality of the building. Kevin Lynch considers the term "aesthetics" too vague, and describes as the "unanalysed residuum," or what is left after the objective analysis of built form.[52] The aesthetics of demountable buildings can be understood as: *visual appearance*, *acceptability by the users* and *appropriateness at the building sites*.

2.3.4.2 Visual Appearance

The visual appearance of objects is communicated by the way in which they reflect and transmit light. According to Harold T. Nefs, this transmission of light is determined by the shape, material, colour and illumination of the object at different levels.[53] The author summarises that the visual appearance of demountable buildings is determined by the combination of scale, construction system, material, colour and illumination at different percentages (Figure. 2.5.).

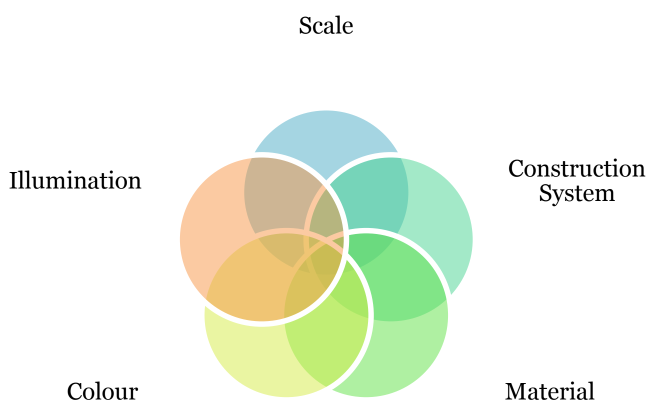

FIGURE 2.5. The aspects of visual appearance in demountable buildings (Summarised by the author)

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[51] Michael Kelly, *Encyclopedia of Aesthetics* (New York: Oxford University Press, 1998), ix.
[52] Kevin Lynch, Tridib Banerjee, and Michael Southworth, *City Sense and City Design : Writings and Projects of Kevin Lynch* (Cambridge, Mass.: MIT Press, 1990), 259.
[53] Harold T. Nefs, "On the Visual Appearance of Objects," In H. Schifferstein and Paul Hekkert, "Product Experience." (San Diego, CA: Elsevier, 2008), http://www.sciencedirect.com/science/book/9780080450896.

2.3.4.2.1 Scale

Mathew Carmona et al. state that "scale is different from size: size represents the literal dimension of an object; scale is the perception of that object relative to other objects around it and to our perception of those objects." [54] They conclude that the scale of a building relates to both human scale and the scale of "adjacent buildings".[55] Alan R. G. Isaac, however, classifies the scale of static buildings in a general way:

TABLE 2.3. The scale of static buildings[56]

Small Scale	Garden retreat; beach huts
Normal Scale	Domestic Public buildings; Village—small townscape
Large Scale	Cityscape; Public building
Gigantic Scale	Regional development; Aircraft hangars; Atomic power stations.

The scale of a demountable building is usually driven by its functional requirements, including its capacity, user groups and the frequency of use and that the buildings can be divided into three groups as large-scale, medium-scale and small-scale.

Large-scale Demountable Buildings

Large-scale demountable buildings are often used for temporary stadium and arena design, large concerts or large stores. The Basketball Arena for London 2012 Olympic and Paralympic Games (Figure. 2.6.) is one of the largest demountable venues ever built. Wilkinson Eyre Architects were appointed to design the arena and according to data from the London 2012 Organising Committee (LOCOG), its construction began in 2009 and took 15 months to complete with a capacity of 12,000 seats. The venue is 115 metres in length, 97 metres in width and 35 metres in height[57] and it is one of the most quickly constructed Olympic Park venues in history. There were 1,000 tons of steel used in the construction of the giant arena frame which was erected in less than three months. The frame's unique arched design ensures that its fabric covering, 20,000 m^2 of recycled white PVC membrane stretched over three different variations of arched

[54] Carmona et al., *Public Places Urban Spaces : The Dimensions of Urban Design*: 189.
[55] Ibid.
[56] Isaac, *Approach to Architectural Design*: 103.
[57] The figures have been estimated by Junjie Xi from Google Earth.

panels, maintains the correct tension.[58] 'Demountability', potential re-use and embodied energy remained on the design agenda throughout. One highlight is that the current design allows for over 2/3 of the materials and elements of the Arena to be re-used or recycled elsewhere, including its foundations.[59] Differing from the foundations of a permanent building, the size of the arena's foundations were kept to a minimum in order to touch the ground lightly. The engineer teams used dynamic thumping to compact the ground with one slab laid under the field of play. Stone footings were then vibrated into the ground to support the footings of the portal frame. Removable steel sheets were driven into the ground to resist the lateral thrust of the portal arches. A scaffold seating system was proven, through simulations by the architects and the LOCOG, to be, with minor modifications so that it could be easily returned to the marketplace, the most suitable seating choice. This system, completely independent of the frame and cladding, sits on precast concrete pads.[60]

After the conclusion of the Olympic Games, during an interview of Jim Eyre of Wilkinson Eyre Architects by Giovanna Dunmall, Eyre said:

> My only regret about the whole thing is that there was no premium allowed to make it more flexible to turn it into more of a system that could be reconfigured…it was so far ahead when it was being designed that nobody would make a commitment to buying it after. They didn't know who would get to use it.[61]

The London 2012 Water Polo Arena, constructed in Stratford, London is also a large, demountable building. With a 5,000 seat capacity, the venue also provided an innovative platform for the future of Olympic architecture. Architecture critic and editor Arthur Wortmann reports that a few other buildings will be partly dismantled after the Games and the capacity of the Olympic Stadium, the work of Populous, will be reduced from 80,000 to 25,000 seats. Zaha Hadid's Aquatic Centre will be altered by removing its two tiered seating wings and converting the building into an elegant and transparent community swimming pool.[62]

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[58] 2011 Olympic Delivery Authority, "London 2012 Basketball Arena-Construction Complete,"(2011), http://www.london2012.com/documents/oda-publications/london-2012-basketbal-arena-construction-complete.pdf.
[59] 2008 Olympic Delivery Authority, "Basketball Arena Planning Application,"(2008), http://www.london2012.com/documents/oda-planning/basketball-arena-planning-update.pdf.
[60] Hattie Hartman and Edmund Sumner, *London 2012 : Sustainable Design : Delivering an Olympic Legacy* (Chichester, West Sussex, United Kingdom: John Wiley & Sons, 2012), 134.
[61] Giovanna Dunmall, "Perspective London," *Mark* 2012, 95-98; ibid.
[62] Arthur Wortmann, ibid., 70.

FIGURE 2.6. - 2.7. The Basketball Arena for London 2012 Olympic Games;[63] The UK Pavilion for Shanghai Expo 2010[64]

Prior to the London 2012 Olympic Games, the UK Pavilion (Figure.2.7.), also known as the Seed Cathedral, exhibited at Shanghai Expo 2010, was also a demountable building. It was designed by Heatherwick Studio (London) and constructed from 60,000 transparent 7.5 metre long optical strands, each of which had embedded, within its tip, a seed.[65] The building was 25 metres in length, 25 metres in width and 20 metres in height. The main exhibition area was 105 m^2 within a 4490m^2 landscape area. The Seed Cathedral was completely dismantled at the end of December 2010, and a proportion of the seeds were donated to schools, universities, research organisations, with some put on sale for charity. Although the Pavilion was almost 18 times smaller than the basketball arena, it had 50,000 visitors each day throughout the duration of the Expo, and it should, for that reason be considered a large scale project.[66]

[63] London Organising Committee of the Olympic Games and Paralympic Games Ltd (LOCOG) 2007, "An Aerial View of the Basketball Arena," (July 27 2011).
[64] Heatherwick Studio, "UK Pavilion Shanghai Expo 2010," (2010).
[65] Ibid.
[66] As discussed above (page 64), the scale of a demountable building is usually driven by its functional requirements, including its capacity, user groups and frequency of use. Because the UK Pavilion attracted 50,000 visitors each day throughout the duration of Expo, it should therefore be considered a large scale project. The UK Pavilion was not included as a case study because it was difficult to conduct field research during the Shanghai Expo 2010 and the designer did not respond to the interview invitation.

Medium-scale Demountable Buildings

FIGURE 2.8. - 2.9. The Temporary Pavilion for the 75th Lisbon 2005 Book Fair; The entrance to the pavilion [67]

Medium scale demountable buildings are often used for temporary exhibitions, community centres, schools and offices. For example, the Temporary Pavilion for the 75th Lisbon Book Fair 2005 (Figure 2.8.-2.9.), was a low-budget, temporary construction project in Portugal. The design team included Marcos Crus, Marjan Collettie, Joao Albuquerque and Shui Liu.[68] The total construction area was 1000 m^2 and consisted of three independent, medium-scale structures; an auditorium for a minimum of 150 people, a self-service cafeteria with an exterior esplanade for 70 people and a separate information pavilion. The project's low-technology construction requirements enabled it to be conceived in only six weeks, including the detailing stages, and fully assembled in four weeks.[69] The designers chose to use internal recyclable metal scaffolding and MDF (Medium-Density Fibreboard) cladding as the main construction materials in order to minimise the costs. The building demonstrated how innovative digital technologies can be applied to low-technology and low-cost construction techniques, with its total budget being under €400,000.

The project aimed to answer two research questions: could a low-technology yet sophisticated and experiential building be created by using the programme, site and budget impositions; and could digital modelling and manufacturing technologies be used to create a good public infrastructure within a limited budget and construction timetable?[70] The temporary Book Fair pavilion is classified here as a medium-scale

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[67] Marjan Colletti, "The Temporary Pavilion for the 75th Lisbon 2005 Book Fair; The Entrance to the Pavilion," (2005).
[68] *The Marjan Colletti Blog;* "Project: 75th FLL, Lisbon Book Fair," blog entry by Junjie Xi, August 15, 2011.
[69] Marcos Cruz and Marjan Colletti, *75th Lisbon Book Fair* (The Bartlett School of Architecture, UCL, 2005), 3.
[70] Ibid., 7.

demountable building because, in comparison to the Basketball Arena and the Seed Cathedral, the temporary Book Fair pavilion was constructed within a shorter timescale with lower budget. It had fewer visitors and exhibited for a shorter time. The author argues that: an important strength of the Book Fair pavilion is that although it served commercial purposes, it was also a research project directed by Dr Marjan Colletti[71] based at The Bartlett School of Architecture, UCL. It is a good example of the collaboration between manufacturing industry and academia and of empirical architecture education, the example of which would be of further benefit if it was similarly replicated within architectural education.

Small-scale Demountable Buildings

FIGURE 2.10. - 2.11. A single micro dwelling;[72] Three dwellings attached together, Space Soon, Roundhouse, Arts Catalysts, London, UK, 2006[73]

Small-scale demountable buildings are often used for temporary residential spaces, mobile shops, portable clinics, exhibitions and indoor or outdoor performances. Sometimes, a small-scale demountable building does not need to be dismantled before transportation, instead being moved and relocated whole. For example, the *Micro Dwelling* is a system for making low cost dwellings of variable sizes (Figure. 2.10.-2.11.). It is designed by N55, an art collective based in Copenhagen, Denmark. The Micro

[71] Marjan Colletti is an architect, educator, and a lecturer at the Bartlett School of Architecture. His research covers the field of digital architecture, exploring the potentialities of a poetic digital avant-garde developed through multi-dimensional computer-aided design software.
[72] N55, "Micro Dwellings, Copenhagen," (2005).
[73] N55, "Space Soon, Roundhouse, Arts Catalysts, London, UK," (2006).

Dwelling consists of moveable housing modules that can form different configurations on land, on water and underwater. It is a multi-functional dwelling system which can fulfil many temporary needs, such as accommodation, storage or exhibition. Each unit can be easily scaled up or down for different purposes. A basic single module is 2.3 metres in height, 2.4 metres in width, and includes 8 hexagonal plates and 6 square plates in 4 mm steel with edges of 831 mm in length. The strengths of the Micro Dwelling include that it is easy to transport due to its small-scale, adaptable in structure and flexible in function, and the construction system can be developed into larger scale projects for multiple purposes.

An interesting example is the newly launched *Soundforms* (Figure. 2.12.-2.13.), a portable and demountable acoustic shell for musical performances. The concept for Soundforms was created by Jason Flanagan, director of London-based architecture practice BFLS, [74] in collaboration with conductor and music producer Mark Stephenson[75]. The project team also included Arup Acoustics and staging specialist ES Global [76] who had expertise in providing solutions for live music, sporting and hospitality events. The concept of designing a high quality performance place was developed into a portable structure that could be used both indoors and outdoors. The acoustic shell has three principle components: an aluminium frame; an inflatable fabric skin; and timber acoustic panelling. The Soundforms can provide a high quality performance space for festival promoters, performers, audiences and broadcasters because it was designed to meet the functional demands of performing outside. Currently, there are three different sizes of Soundforms (Table 2.4.): Mark I (14w×21×6.5h), Mark II (17×27.3×8.0) and Mark III (20.9×33.5×10.0). The entire range shares the same shape and concept yet are designed to be suitable for different locations for: small, medium and large events.[77]

[74] BFLS is an architectural practice based in London, with offices in Prague and Hong Kong. Their projects cover workspace, living space, retail, leisure, public building, master planning and education.
[75] Mark Stephenson is a British conductor and producer who composed and conducted the score for the Oscar-winning 2006 animated short film Peter and Wolf.
[76] ES Global is a company based in London that provides solutions for music, sporting, corporate and hospitality events. Their projects cover from interactive installations to re-locatable structures that tour the world.
[77] Soundforms, "Soundforms - Range," http://www.soundforms.co.uk/products.php.

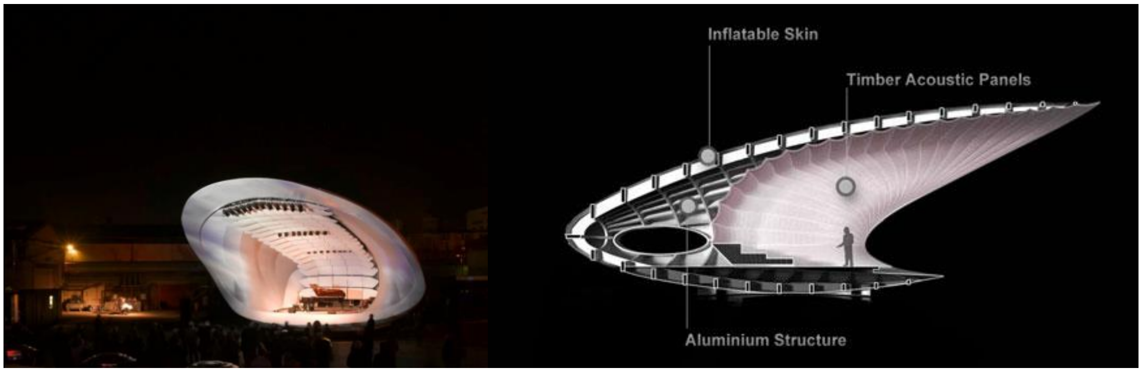
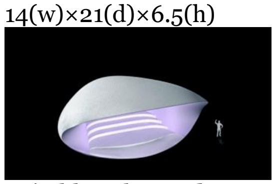
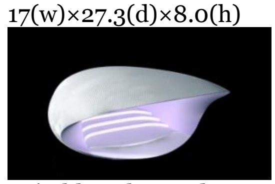
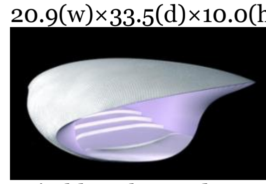


FIGURE 2.12. - 2.13. The Soundforms during a performance;[78] The Soundforms design[79]

TABLE 2.4. The range of the Soundforms [80]

	Ranges		
Name	Mark I	Mark II	Mark III
Dimensions (m)	14(w)×21(d)×6.5(h)	17(w)×27.3(d)×8.0(h)	20.9(w)×33.5(d)×10.0(h)
Image			
Use	Suitable to be used at courtyards, quadrangles, town squares and indoor corporate atria. Accommodating up to 23 musicians with a sound protection audience reach of up to 750.	Suitable to be used at large gardens, city squares, exhibition centres, shopping centres, large galleries and museums. Acoustically designed for 750 audiences without amplification, amplification required to reach up to 2,000.	Suitable to be used at large-scale festivals, parks, large public outdoor arenas, exhibition centres, opera galas. Accommodating up to 70 musicians and can research a large number of the audience between 2000-4000.

A final example is the *Mina Improved Tent Project*, designed as a collaboration between the Ministry of Public Works and Housing, Kingdom of Saudi Arabia and SL-Rasch Gmbh Special and Lightweight Structures in 1996. Each tent is at a scale of 8×8 m^2 per unit. Although each individual tent is small, 40,000 of them have been erected in a desert valley.[81] The argument here is that the scale of demountable buildings strongly links to its function and surrounding environment. The flexible structure allows this building type to be adapted easily and according to specific needs.

[78] Nick Guttridge, "Soundforms 2012 Prototype BFLS," (2012).
[79] Soundforms, "Soundforms - Components," (2011).
[80] ———, "Soundforms - Range".
[81] More details about this project can be read in Appendix B The Mina Improved Tent Project Questionnaire.

FIGURE 2.14. - 2.15. A tent unit; The Mina Tents Valley[82]

Summary

The scale of a demountable building is usually determined by the size of construction site, the size of useable space, the number of users (visitors), the quantity of construction materials, number of construction team members, the budget (costs) and assembly time. The scale of demountable buildings is not often a fixed term because their construction systems are flexible and adaptable. Different scale scenarios can be created according to the specific function needs by adding or reducing construction components, for example, according to the clients' needs, by adding components a small-scale project can be transformed into a large-scale project.

[82] Moshabab Aljarman, "The Mina Tents Valley," (2003).

2.3.4.2.2 Construction Systems

The most common construction systems used in demountable buildings currently include: modular, flat pack, tensile, pneumatic and combined systems.[83] This section discusses each of the construction systems in detail with selected contemporary examples.

Modular Construction

A modular construction system is based on modules, of certain standard sizes and multiples of those sizes, and it is often associated with industrialised buildings and prefabrication. Modules are often constructed or produced off-site and the construction systems can be developed for an entire demountable building, such as temporary shipping container buildings or ready-made prefabricated buildings.

The term “modular” is used to describe the construction system, while the term “module” means “the basic dimension of a geometric classification system”.[84] Modular classification includes a basic module, which is the increment used for dimensioning, multi-module, which is the standardised multiple of the basic module, and structural module which is a multiple of multi-modules and which determines the co-ordinating dimensions for the structure.

To illustrate, the Swell House, (Figure.2.16.-2.17.) designed by the Office of Mobile Design (OMD) is an ‘S’-shaped modular structure. The building components were assembled in a factory and transported to site. All the independent ‘S’ modules were deployed at the site and bolted together quickly. Electrical, plumbing, and information technologies were concealed within the cavities as part of this standardised modular system.[85] As previously discussed, the micro dwellings are a further example of modular construction system.

[83] Kronenburg, *Houses in Motion*: 10.
[84] Gerald Staib, Andreas Dörrhöfer, and Markus J. Rosenthal, *Components and Systems : Modular Construction : Design, Structure, New Technologies* (München; Basel [Switzerland]; Boston: Edition Detail, Institut für internationale Architektur-Dokumentation ; Birkhäuser, 2008), 44.
[85] Office of Mobile Design, "SwellHouse," http://www.designmobile.com/swell.html.

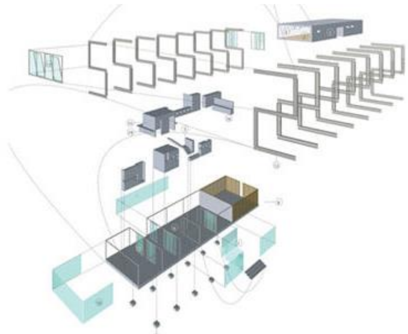


FIGURE 2.16. - 2.17. The ‘S’-shaped modular frame of Swell House; The Swell House[86]

Modular construction has been recognised as an effective solution to the challenges of rapid construction. Modular building components can be simply and quickly organised into different configurations depending on their geometric and construction rules. The prefabrication of modules off site, usually within controlled environments, allows for a consistency of quality unachievable ‘on site’, speed of on-site erection, cleaner and smaller sites due to the lack of need for raw materials and ‘wet’ trades. In addition, because modular buildings are constructed from individual modules, they can be either expanded or reduced in scale according to the design requirements. Modular construction is, therefore, a flexible construction model, but it is disadvantaged by the fact that building components in a modular construction system can only be used within that particular system and the range of design is limited due to the rigidly determined function of the building parts.[87]

Flat Pack

Flat pack structures are normally delivered in parts and constructed on site. The components are often pre-made in factories/studios and the buildings are relatively easily constructed. Traditional flat pack demountable structures include tents, yurts, marquees and domes.

[86] Office of Mobile Design, "The ‘S’-shaped Modular Frame of Swell House; Swell House Overview.
[87] Staib, Dörrhöfer, and Rosenthal, *Components and Systems : Modular Construction : Design, Structure, New Technologies*: 42-43.

FIGURE 2.18. - 2.19. The Cluny Summer Pavilion; A close view of the pavilion[88]

A non-traditional example of flat pack construction, the *Cluny Summer Pavilion*, (Figure 2.18.-2.19.) designed by two graduate Part II architects Sarah Considine and Melanie Bax[89], was developed from the initiative 'We ♥ Suburb' project, funded by RIBA (Royal Institute of British Architects), the Big Lottery Fund[90] and the University of Sheffield. The pavilion was a flat-pack, temporary, timber, community facility which was installed in Cluny Park, Southend-on-Sea. It was dismantled and stored for re-use the following year by the local community. This project is a further example of the previous argument that small-scale demountable projects can establish the reputation of young architects or designers. Furthermore, they are a strong resource for empirical architectural education because they can be used for students to practice their design skills.

Tensile

Tensile structures are formed mostly from components acting in tension rather than in compression. They are built in such a way that structural elements are subject to tensile forces. Most commonly used tensile structures include tents and marquees. The first

[88] Sarah Considine and Melanie Bax, "Cluny Summer Pavilion," (2011).
[89] Sarah Considine and Melanie Bax are both Masters graduates from The University of Sheffield, UK. They are interested in community participation and how the role of the architects can be expanded to include social and political context. They received £5,000 from the RIBA ICE Bursary in 2010.
[90] The Big Lottery Fund (BIG) is the largest distributor of Lottery money in UK. It is responsible for delivering 46% of all funds raised for good causes by the National Lottery. BIG has awarded over £ 4.4 billion to projects supporting health, education, environment and charitable purposes and most of the funding has been awarded to voluntary and community sector organisations.

tensile structure was erected by Vladimir Shukhov[91] in 1895,[92] and they are widely used because of the ease of fabrication and construction, ability to bear loads over long period of time and because of their light-weight properties which make them easy to transport. Tensile roofing systems are common in structures like sports stadiums, where a large space needs spanning with a minimum of internal columns or supports. Tensile structures rely on strong anchor points to keep them stable. Heavy rain and snow could cause the structure to collapse if the anchor points are shifted in a loose foundation.

The following two examples, the *Mobile Summer Tent* (Figure 2.20.) and the *Starwave Tent* (Figure 2.21.) designed by SL-Rasch Gmbh Special and Lightweight Structures, are typical of tensile demountable structures. The Mobile Summer Tent weighs 160 kg and covers 90 m^2. It has been used as a shading structure and rain shelter for outdoor events. The Starwave Tent for 'La Biennale di Venezia 1996' (The Venice Biennale) was a mobile tent which did not require fixed anchoring into concrete foundations. This tent could be deployed and dismantled quickly in any location and weather conditions because the tension forces and wind loads were counterbalanced by containers filled with pebbles.

FIGURE. 2.20. - 2.21. Mobile Garden Tent for the Theodor-Heuss-Stiftung, Stuttgart;[93]
Starwave Tent for 'La Biennale di Venezia 1996', Italy[94]

[91] Vladimir Shukhov was born in 1853 and was a Russian scientist, engineer and architect. He was renowned for his works on new methods of analysis for structural engineering that led to breakthroughs in industrial design of world's first hyperboloid structures, lattice shell structures, tensile structures and gridshell structures. Exhibition "Building the Revolution: Soviet Art and Architecture 1915-1925" was held in Royal Academy of Arts between 29 October-22 January 2012. The exhibition examines Russian avant-garde architecture made during a brief but intense period of design and construction that took place from 1922 to 1935. More information about Constructivists and Vladimir Shukhov can be found in the exhibition related materials.
[92] Ruby and Ruby, *Re-inventing construction*: 340.
[93] SL-Rasch Gmbh Special and Lightweight Structures, "Mobile Garden Tent for the Theodor-Heuss-Stiftung."
[94] ———, "Starwave Tent and Umbrellas for 'La Biennale di Venezia 1996', Italy," (1996).

Pneumatic

Pneumatic structures are inflatable and, therefore, are supported by air pressure. They are rapidly demountable and self-supporting, with pneumatic membranes. As architect Antoine Stinco states:

> Air-supported structures are in a permanent state of unrest, sensitive to the smallest environmental change. They are not only volatile (thus requiring heavy anchorages) but cruelly organic and vain; they constantly present the inhabitant with a spectacle analogous to his own condition. Air-inflated structures, by contrast, comprise more stable systems of discrete pneumatic membranes and "airbeams."[95]

The most commonly used pneumatic building components and structures include inflatable tents and roofs, for example *Air Forest* (Figure 2.22.-2.23), designed by Mass Studies[96] as a temporary pneumatic structure and installed in City Park, Denver, Colorado, USA, for Dialog: City, an arts and cultural event during the Democratic National Convention 2008. The task was to create a temporary public space for a series of small cultural events including the Yoga Health Festival and small parties. The Air Forest was used to fill an open space and offer temporary, multiple functions for visitors. City Park in Denver has a large open grass field space with Feril Lake in the centre, which was an ideal location for a temporary installation. Air Forest was a 56.3 metres long and 25 metres wide pneumatic structure, composed of 9 hexagonal canopy units, at 4 metres in height. The units were interconnected as one large piece of fabric, which was then inflated from the 14 air-blowers that were located inside the base of its 35 columns. The structure provided shade from the sunlight for the public and the nylon fabric was coated with a gradient of silver dots which reflected the colours from the surrounding environment. At the end of the event, Air Forest was packed into a 1 m^3 box to be used in the future.

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[95] Marc Dessauce and York Architectural League of New, *The Inflatable Moment : Pneumatics and Protest in '68* (New York: Princeton Architectural Press, 1999), 81.
[96] Mass Studies was founded by Korean architect Minsuk Cho in 2003, as a critical investigation of architecture in the context of mass production, intensely over-populated urban conditions, and other emergent cultural niches that define contemporary society.

FIGURE 2.22. - 2.23. Air Forest installed in City Park, Denver, Colorado, USA; A close view of Air Forest[97]

Generally, most pneumatic structures can be both easily and quickly inflated and deflated. According to artist Alan Parkinson, who has 20 years of experience in designing pneumatic structures, the biggest challenge is the strong wind,[98] evidenced by a tragedy on 22 July 2006. Two people died when the huge, inflatable *Dreamspace V*, designed by British artist Maurice Agis[99], left its moorings and was lifted 9 metres high into the air in Chester-le-Street Riverside Park, County Durham (Figure 2.24.). Paul Stokes reported that there were two factors which may have caused this tragedy, one being that the hot summer turned the inflatable structure into a 'hot air balloon', and the other was that the structure was subject to a knife attack when it was on display at Liverpool Metropolitan Cathedral (Figure 2.25-2.26.) a month earlier. At Liverpool three of its units were badly damaged and had to be replaced.[100] However, pneumatic structures offer many new and advantageous build options and research evidence shows that the scale of the project is normally proportional to the risks attached. To this end, more investigations are emerging into the structural behaviour of pneumatic installations.[101]

[97] Jason Walp, "Air Forest," (2008).
[98] Alan Parkinson, in discussion with the author, April 2011.
[99] Maurice Agis was born in 1931. He was a British sculptor and artist who studied painting and sculpture at St. Martin's School of Art in London and went onto postgraduate works on De Stijl at the Dutch Ministry of Education in 1967. He created inflatable art installations in many countries including Britain, US, Australia and Germany. He died in 2009, three years after the Dreamspace accident.
[100] Paul Stokes, "Sun Turned Inflatable Artwork into a Killer," http://www.telegraph.co.uk/news/1524741/Sun-turned-inflatable-artwork-into-a-killer.html.
[101] The V International Conference on Textile Composites and Inflatable Structure-Membranes 2011 was held in Barcelona, Spain, 5-7th October 2011. The objectives of the conference were to collect and disseminate state-of-the-art research and technology for design, analysis, construction and maintenance of textile and inflatable structures.

FIGURE 2.24. - 2.26. CCTV footage released by the police of the Dreamspace inflatable sculpture was lifted up into the air;[102] Dreamspace installed in front of The Metropolitan Cathedral, Liverpool;[103] Inside the Dreamspace[104]

Combined System

Some demountable buildings contain more than one structural system, for example, the Fireproof Tents for the Mina Tent City, Makkah, K.S.A., a design which combines both modular and tensile systems.

FIGURE 2.27. - 2.28. A single 8x8 m tent; The Tent City in the Mina Valley[105]

The huge tent city in Mina was deeply affected by an explosion on 16 April 1997. More than 30,000 tents caught fire, leaving hundreds of pilgrims dead and thousands injured. The host country of Saudi Arabia, responsible for the security of the holy place, had to devise a solution, before two million more believers arrived in the Spring of 1998. Designs by Dr. Bodo Rasch's company[106] prevailed over others that suggested the use of

[102] Durham Police, (2006).
[103] Liverpool Daily Post, "Brouhaha International Vow to Carry on after High Court Verdict on Dreamspace 5 Deaths," (2011).
[104] Sandy Britton, "Dreamspace in Liverpool," (2006).
[105] SL-Rasch Gmbh Special and Lightweight Structures, "Fireproof Tents for the Mina Tent City, Makkah, K.S.A.," (1997).
[106] Mahmud Bodo Rasch was born in 1943 in Stuttgart, Germany. He is the son of architect Bodo Rasch (1903-1995) and painter Lilo Rasch-Nägele. He completed his PhD under the supervision of Professor Frei Otto and Egbert Kossak in 1980 on the tent cities of the Hajj, at the University of Stuttgart.

materials such as concrete or corrugated iron. By contrast, Rasch's design used membranes for construction with an appearance similar to traditional pilgrims' tents.

The 8×8 metre fire proofed tents were manufactured industrially. Non-combustible Teflon-coated glass fibre sheets were produced specifically for the tents in factories. These non-combustible Hajj tents were designed in such a way that they reflected the form, and arrangement of traditional pointed Hajj tents, which are traditionally made of cotton and are supported by bamboo masts. As a consequence, the appearance of the tent city in the Mina Valley, comprised of tents constructed from this new material, remains much the same. The funnel-shaped tent roofs produce natural ventilation through a central opening which is covered by a membrane hat. The square shaped tent modules are set up in groups to form larger tent units with outer and inner membrane walls, doors and ventilation flaps. The layout of the membrane walls facilitate the division of space inside the tent units into private sections of 4×4 metres. The wall and roof membranes are supported by hot dip galvanised steel frame structures that are set into concrete block foundations. All membrane walls can be rolled up easily to create larger spaces and increase natural ventilation. The membrane partitions can be rolled up after the Hajj season to create an open space to allow maintenance work of the Mina Valley area. Every Hajj tent is equipped with a desert cooler to improve the climatic comfort for the pilgrims, and all electrical installations, including plugs and switches, are integrated into the tubular steel frames of the tents. There were 12 different tent module types designed under the same principle, and the tents were then adapted to meet the requirements of the authority.

Parametric design [107] has become a new architectural design methodology that challenges the traditional top-down design methods, and it can often been seen in demountable buildings because it uses computational algorithms. The design pattern results are usually regular and are a series of repeating structures. These key features are ideal for modular and flat pack construction systems in demountable building design, with the Embedded Project - *For Earts 2008 Shanghai* (Figure 2.29.), designed

[107] Parametric design is a design method, which uses computer programming to create variations of a design following specified criteria. Parametric design allows the creation of complex geometries that challenge the traditional construction methods.

by HHD_FUN[108] in collaboration with Aaajioa,[109] being a combination of modular and flat pack construction systems.

FIGURE 2.29. - 2.30. The embedded project - For Earts 2008 Shanghai;[110] Inside the factory[111]

In For Earts 2008 Shanghai, the faces of the box were designed using a recursion algorithm, based on a triangular fractal pattern. Each triangle is sub-divided again and again to create smaller and smaller triangles and a denser pattern. At each stage, two out of the three segments are sub-divided so that one large segment remains intact to create variation in scale across the surface. At each division, the new triangles are raised perpendicularly by 12 cm to create the three-dimensional surface pattern on the faces of the installation. The designer, Wang Zhenfei, says that blueprints are not necessary during construction because once the workers understand the principles of the design (sub-dividing the triangular fractal pattern) they can manufacture the elements quickly and construct them easily without the designer's attendance (Figure 2.30.). As such, this exemplifies how demountable buildings can be easily constructed and dismantled.

[108] HHD_FUN is a design and research studio based in Beijing, China. The studio has strong interests in applying computational techniques, geometric principles and algorithms in architectural design. Wang Zhenfei and Wang Luming are two Principals of HHD_FUN. They both graduated with an advanced master of architecture from Berlage Institute Netherlands in 2007.
[109] Aaajiao (Xu Wenkai) is a contemporary Chinese digital artist.
[110] HHD_FUN, "Embedded Project-For Earts 2008 Shanghai-with Aaajiao," (2008).
[111] Ibid.

Summary

The majority of small-scale public, demountable buildings are pre-fabricated and pre-manufactured building systems. All elements are fabricated by a single manufacturer ("closed systems"[112]) or by different manufacturers ("open systems"[113]). Pre-fabricated building systems can be evaluated throughout manufacturing process, delivery, construction and deployment, and small improvements to the building components whilst in the factory can improve building quality before it is transported to site. Future developments could enable the functional performance of demountable buildings to be quantified by analysing building components in the factory, and, the growth or reduction in the needs of demountable buildings can be measured through analysing the building elements at their point of production.

2.3.4.2.3 Material

Within the contemporary, static building construction industry, commonly used materials include: glass, concrete, wood, metals and plastics. In the contemporary, demountable, building industry, wood, bamboo, metals and plastics have been widely used because of their relative light weight and flexibility. Glass and concrete are generally less common in demountable construction due to their respective characteristics of high cost and heavy weight. Evidence shows, however, that increasing demand for demountable buildings has encouraged architects to be innovative in the use of materials, for example; paper tubes and cardboard.

Wood

Wood is natural, organic, lightweight, strong, readily accessible, and simple to work with in construction. Its wide variety of: colours, textures, grain patterns, and fragrances give designers a versatile, adaptable and expressive tool for construction. Wood has been used as an important architectural material for centuries because of its

[112] Staib, Dörrhöfer, and Rosenthal, *Components and Systems : Modular Construction : Design, Structure, New Technologies*: 42.
[113] Ibid., 43.

warm aesthetic and easy workability.[114] An example of a timber demountable building is the *Norway Pavilion*, (Figure 2.31.-2.32.), designed by Helen & Hard Architects (Norway) for the Shanghai Expo 2010. The pavilion was constructed from 15 wooden ‘trees’, made from pine trees from Norway and bamboo from China. All the ‘trees’ were easily dismantled and re-erected at further locations to serve as shaded park installations, playgrounds and meeting places.

FIGURE 2.31. - 2.32. The Norway Pavilion; The interior design of the Pavilion[115]

In addition to more traditional timber construction, reclaimed timber and irregular plywood forms can also play an important role as a demountable construction material. For example, *The Jellyfish Theatre* (Figure 2.33-2.34.), designed by artists Folke Köbberling and Martin Kaltwasser,[116] was made from entirely re-cycled and re-claimed materials. The 120 seat theatre was constructed at Marlborough Playground in Union Street, London, during the summer of 2010, as a part of the London Festival of Architecture 2010 exhibition.

[114] Victoria Ballard Bell and Patrick Rand, *Materials for Design* (New York: Princeton Architectural Press, 2006), 107.
[115] Helen & Hard Architects, "The Norway Pavilion; The Interior Design of the Norway Pavilion; The Furniture in the Norway Pavilion," (2010).
[116] Folke Köbberling was born in1969 in Kassel, Germany. She studied in Fine Arts in University of Kassel and studied in architecture in UdK Berlin/University of Arts, Berlin. Martin Kaltwasser was born in Münster in 1965. He studied in Fine Arts, Akademie der Bildenden Künste Nürnberg/Academy of Fine Arts, Nuremberg and studied architecture in Technical University, Berlin. Folke Köbberling and Martin Kaltwasser live in Berlin, Germany.

FIGURE. 2.33. - 2.34. The Jellyfish Theatre Outside; The Jellyfish Theatre Inside[117]

The project was constructed by volunteers from The Oikos Project[118] who spent two months preparing to welcome their first audience. The Jellyfish Theatre was dismantled and recycled in October 2010. An advertisement was made by the administrator of The Oikos Project online, announcing free wood available, including; 800 pallets, 700 m^2 of sheet material, plywood sheets, thick floor joists, general timber, 12 doors, foldable wooden tables, wooden chairs, boxes and wicker chairs. The theatre project presented an informal atmosphere that suits the theme of the play. As Protozoa[119] stated "It was a new beginning. A chance to do things better this time."[120] The Jellyfish Theatre is an example of a temporary building, constructed by volunteers, without professional architectural training, which offers both functional and aesthetic considerations and is wholly recyclable.

Bamboo

Bamboo is a giant, fast-growing grass which has been used as a building material for centuries, primarily in Asia, Africa and Latin America where there are more than one billion people who depend on bamboo for shelter and comfort. Many people, particularly those living in the rural areas of less developed countries, live in bamboo houses and use bamboo furniture. Bamboo is strong and flexible, very light and is a renewable and recyclable material. There is currently no documented evidence of the

[117] Folke Koebberling/Martin Kaltwasser, "Jellyfish," (2010).
[118] The Oikos Project is a theatre project proposed by The Red Room theatre in partnership with The Architecture Foundation and in association with The Junction—a cultural venues centre.
[119] Protozoa is the name of a play by Kay Adshead. It was performed from23 September to 9 October 2010.
[120] Oikos Project 2010, "The Plays," http://www.oikosproject.com/the-plays-2/.

durability of bamboo building methods, however, although longevity can be considerably extended by protecting the material from insect attack, mould, rot and fire, and by proper harvesting (bamboo can crack if it is not properly matured and dried before being worked).

FIGURE 2.35. - 2.36. Foundation pads cast with bamboo connection; Bamboo constructed roof[121]

In Southeast Asia, bamboo is a common construction material which has been widely used for transitional housing (Figure 2.35-2.36.). After an earthquake measuring 6.0 on the Richter Magnitude scale struck the south-eastern corner of Jogyakarta Province in Central Java, the Indonesian Government committed to providing permanent housing for every affected family. With a large number of houses destroyed (300,000), and the rainy season imminent the government was slow to respond and, therefore, member organisations[122] of the IASC Emergency Shelter Cluster worked closely to develop guidelines for locally appropriate transitional bamboo shelters.

[121] IFRC (International Federation of Red Cross and Red Crescent Societies), "Indonesia, Jogyakarta-2006-Earthquake in Shelter Project 2008," (IASC Emergency Shelter Cluster, 2008), 43.
[122] The member organisations of the IASC Emergency Shelter Cluster include: the UN High Commissioner for Refugees (UNHCR) and the International Federation of Red Cross and Red Crescent Societies (IFRC).

FIGURE 2.37. - 2.38. A completed transitional shelter built through cash grants; A transitional bamboo shelter built on the site of a destroyed house [123]

The subsequent shelters (Figure 2.37-2.38.) were 4×6m (minimum 2m height) and used simple construction materials Each shelter consisted of bamboo mats; (6 for the walls, 3 for the ceiling, 1 for the door, 12 around poles for columns of 0.91 m diameter x3 m length), 11 around poles for beams and roof joists (7.5cm diameter x 3m length)] 7 beams of timber for fixing the mats, 3×15 m^2 of reinforced plastic sheeting, 2.2 kg of nails (the sizes of which were 5cm, 7.5cm and 10cm in length); 1kg of wire, 3 hinge units and 1 lock unit.

The project was successful in its choice of materials because it kept funds in the local economy and engaged well with local communities. Following their emergency use, the transitional shelters were dismantled and elements were reused locally in kitchens, sheds, small shops, workshops and storehouses. There was a total of 25 million bamboo sticks used in the response, of which 5 million were reused by the Shelter Cluster, 3 million by the Indonesian government, and 10-15 million by other communities.

The Shelter Cluster reports, however, show the management of growing clumps of bamboo was not integrated into the transitional shelter programme, that much bamboo was clear-cut and harvested using non-sustainable techniques, and that as a result, the Java bamboo forest was deeply affected, with some areas of this forest taking ten years to replenish and other areas which will not fully recover.[124]

The lesson learned in this case is that; although local material supply has been encouraged in the construction of demountable buildings, designers and project organisers need to consider the local ecology, especially if large quantities are required.

[123] Societies), "Indonesia, Jogyakarta-2006-Earthquake in Shelter Project 2008," 46.
[124] Ibid., 45-47.

Where a local ecology circle is damaged from a natural and social perspective, a project cannot be considered sustainable.

The IASC Shelter project is a low-technology example built by non-professional people using traditional construction skills. A contrasting example of bamboo construction is the German-Chinese House (Figure 2.39-2.40.), exhibited at the Shanghai Expo (from 1 May to 31 October, 2010), and designed by Markus Heinsdorff,[125] which was a demountable project combining both traditional and high technology. Markus Heinsdorff has a rich experience in using bamboo as a construction material. Before he went to China, he had experimented with bamboo on various levels in other parts of Asia, and had designed structures using traditional materials with high technical performance.

FIGURE 2.39. - 2.40. German-Chinese House, Shanghai, China; An inside view of the pavilion[126]

This bamboo pavilion was a 2-storey membrane structure, 25 metres in width, 10 metres in depth and 8 metres in height. It provided for the functional needs of exhibition, entertainment and conferencing, and it was presented as a pioneering and environmentally friendly building to raise awareness of using sustainable materials for building construction. The structure was designed to be demountable and required all the materials, including the roof skin of polycarbonate membrane, to be either reusable

[125] Markus Heinsdorff was born in Germany in 1954. He was trained from 1974-1976 as a stonemason and goldsmith. He studied in sculpture from 1976-1981 in the Academy of Fine Arts in Munich, Germany and has been studying in design and technical possibilities of bamboo for many years in Asia. He has practised as a sculptor and an architect, and his work covers installations, exhibitions and permanent buildings, as well as being devoted to teaching around the world. His most recent project is Mobile Space Metro Tour, which will be 14 pavilion object buildings for the occasion of completing 60 years of Indo-German diplomatic relations, a collaborative celebration titled “German and India 2011-2012: Infinite Opportunities”. The Mobile Space pavilions will be exhibited as textile buildings incorporating membranes and structural steelwork, they will be set up for ten days each starting in Mumbai in April 2012 and then move on to Bangalore, Chennai, Delhi and Pune subsequently.

[126] Markus Heinsdorff, "Expo 2012, German-Chinese House, Shanghai, China," (2010).

or recyclable. Almost all the materials and components were manufactured on site or in other parts of China. The design technology and connecting elements used throughout the pavilion were developed in cooperation with Chinese and German companies and universities. The roof, façades and interior columns were designed to reference traditional paper-folding techniques. The transparent façade is made self-stabilising by its faceted surfaces and additional cable tensioning. Illumination of the façade serves to light up the interior and the surrounding environment. Following the Expo, the German-Chinese House was dismantled and transported to Hangzhou, 190km away from Shanghai, where it was rebuilt near to the museum buildings designed by architects Herzog & de Meuron, Steven Holl and David Chipperfield. [127] Evidently, bamboo is no longer merely a "poor man's building material",[128] but rather, it has great potential in making a variety of products, such as furniture, musical instruments and toys. Meanwhile, it creates many opportunities for innovation in demountable building design that will bring economic benefits to the bamboo market.

Paper Tubes and Cardboard

Paper tubes and cardboard are not commonly used as building materials, however, their potential for construction has been investigated by several architects, including Shigeru Ban Architects in Japan, Cottrell & Vermeulen Architecture in the UK and Peter Stutchbury Architecture (formally Stutchbury and Pape) in Australia. Shigeru Ban is a contemporary architect who has special expertise in using paper as a building construction material. He has used recycled cardboard tubes to build a wide variety of structures; from shelters for earthquake victims to pavilions for exhibitions, and from churches to houses. Ban's *Paper Tubes* construction was approved under Japan's Ministry of Construction, Article 38 of the Building Standards Law in 1993, although before this time he had used paper-tubes in a few projects, including *Paper Arbor*, 1989, *Odawara Hall and East Gate*, 1990 and *Library of a Poet* 1991. To satisfy health and safety issues, the paper tubes need to be treated with waterproof or fireproof paint. The method used by Shigeru Ban Architects is to soak the paper tubes completely in the paint and leave them to dry (Figure 2.41-2.42.). Regular timber sections attached to

[127] Christian Baumert et al., *Markus Heinsdorff, Design with Nature : Bamboo Architecture: Die Bambusbauten. The Bamboo Architecture* (München: Hirmer, 2010), 119.
[128] Ibid., 13.

plywood have been inserted inside the tubes to support the columns structurally (Figure 2.43.).

FIGURE 2.41. - 2.43. Two volunteers soaking a paper tube in the fire proof paint; Pater tubes after treated with fire proof paint; Timber inside a paper tube to support the tube structure [129]

The Paper Arbor (Figure 2.44.-2.45.) was the first in a series of paper tube constructions. Manufactured as form work for circular concrete columns, the tubes were then themselves used structurally. Forty-eight of these tubes, 325 mm in diameter, 15 mm thick and 4 metres high were treated with paraffin for waterproofing and fitted in a circle onto a pre-cast concrete base. The columns were stiffened with a glue compound and joined at their heads by a wooden compression ring. The roof consisted of tenting fabric, hung from tension wire arranged in a spoke-life configuration. After the structure was dismantled, the strength of the paper tubes was analysed. Despite being subject to six months of wind and rain, a hardening of the glue and moderate exposure to ultraviolet rays had actually resulted in increasing the compressive strength of the tubes.

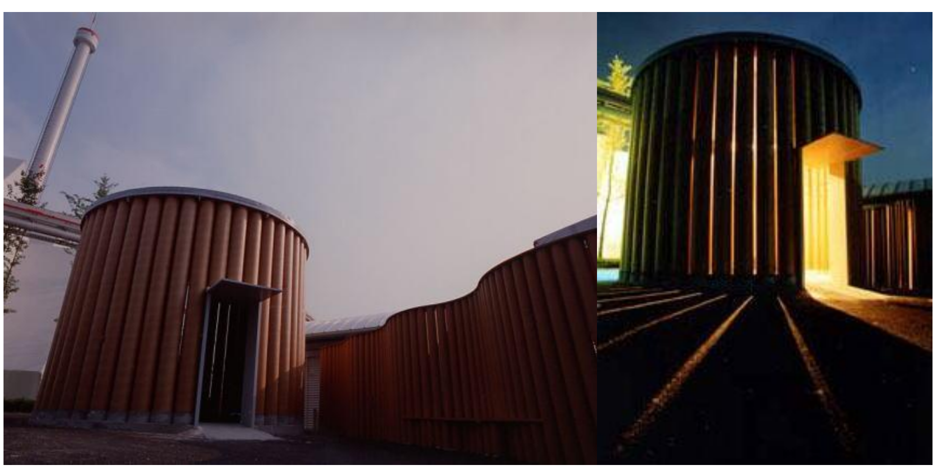

FIGURE 2.44 - 2.45. Paper Arbor-Nagoya, Japan, 1989; Paper Arbor in the Evening[130]

[129] Shigeru Ban Studio-Kyoto University of Art and Design, "February, 02, 2012," (2012).

In an interview by writer, photographer and film maker Roland Hagenberg, Ban was asked how he came up with the idea of using paper tubes. He explained:

> I didn't have enough money to use expensive wood for the set-up of the exhibition for Finnish architect Alvar Aalto. The idea that wood is wasted after the show bothered me as well. At that time I still had some leftover paper-tubes from a previous project in my office. I thought; what a pity a throw them away, better use them for Alvar Aalto. Issey Miyake's MDS Gallery (Figure 2.46.-2.47.) in Tokyo became the first permanent paper-tube structure building, after I got the permission from the government.[131]

FIGURE 2.46-2.47. Miyake Design Studio Gallery-Shibuya, Tokyo, Japan, 1994; The Interior Design of the Miyake Design Studio Gallery-Shibuya[132]

Between 1997 and 2011 there have been 27 projects, both temporary and permanent, designed by Ban's team and made from paper tubes. Apart from Shigeru Ban, there are a few architects who have also used paper tubes and cardboard as primary construction materials, such as the Westborough Primary School Cardboard Building, designed by Cottrell and Vermeulen Architecture in Kent, which was constructed from cardboard. The details of this project are discussed in Section 2.4.1.2.

Another example is a prototype cardboard house (Figure 2.48-2.50.) for the House of the Future exhibition, staged in Sydney Olympic Park in 2005 and designed by Peter Stutchbury Architecture. In this project, Stutchbury's team worked with an architect from Ian Buchan Fell Housing Research Centre[133] who had experience of paper and

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[130] Shigeru Ban Architects, "Paper Arbor-Nagoya, Japan," (1989).
[131] Roland Hagenberg and Zengrong Wang, *20 Japanese Architects : Interviews and Photos* (Taipei: Garden City Publishers, 2009), 71.
[132] Shigeru Ban Architects, "Miyake Design Studio Gallery-Shibuya, Tokyo, Japan," (1994).
[133] The Ian Buchan Fell Housing Research Centre was established in the University of Sydney in 1966. It is funded by the estate of the late Ian Buchan Fell who graduated in Architecture at Sydney University in 1929

cardboard construction. The aim of this project was to develop an affordable house which would inhabit the environment sustainably, and be as easy to assemble as flat-pack furniture. The cardboard was made from 90% recycled materials with a waterproof high-density polyethylene outer layer. The cardboard house weighed about 2000 kgs and could be easily delivered on a truck flatbed.

FIGURE 2.48 - 2.50. The Cardboard House in Sydney, 2005; Inside the Cardboard House; The Cardboard House at the exhibition[134]

Artists and interior designers have also shown an interest in using cardboard for exhibition design, both for aesthetic and functional purposes, for example, the Cardboard Café (Figure 2.51-2.52.), designed by B3 Designers and constructed during The London Design Festival 2008, which was made out of 8000 cardboard boxes edged with fluorescent orange. The café included a temporary bar, restaurant and retail design experience. All "cardboard bricks" were installed together using hot glue guns and according to B3 Designer, it was; "an exercise in creating high impact architectural interior design with minimal materials."[135]

and died in 1961. The Centre was generally established for the purpose of research into aspects of social housing.

[134] Brett Boardman and John Gollings, "Housing the Future," (2005).

[135] B3 Designers, "Cardboard Café, London," http://www.b3designers.co.uk/exhibition-cardboardcafe.html.

FIGURE 2.51 - 2.52. The Cardboard Café bar area; The seating area and two towering arches[136]

Paper tubes and cardboard have become popular materials for contemporary demountable building construction due to their natural colour and warm texture. However, there are many other aspects that have not been explored thoroughly, for example whether different colours can be applied to paper tubes; how ventilation problems can be overcome, as paper and cardboard absorb the heat from solar gain quickly in the summer time, and how to improve weather resistance. Papers tubes and cardboard are not new materials, but they are full of potential because of they are made from sustainable, raw materials and are highly recyclable.

Natural Fibre

Natural fibre insulation refers to a method of insulating buildings with natural, renewable, or agricultural waste materials such as straw, hemp, cotton, wool, or linseed. The varying properties of natural fibres can sometimes cause problems when used as insulating materials, due to, low inflammation temperatures and, therefore, high flammability. To address these issues, materials can be treated with flame-retardant chemicals.[137]

[136] B3 Designers 2012, "Cardboard Café London," (2008).
[137] Ruby and Ruby, *Re-inventing construction*: 230-34.

FIGURE 2.53. The Spanish Pavilion at Shanghai Expo 2010[138]

An example renowned for using natural fibre as a major construction material, is the Spanish Pavilion (Figure 2.53.) of the Shanghai Expo 2010, designed by Benedetta Tagliabue[139], an Italian architect educated in Venice and who is currently based in Spain. This four-story steel structure was built on a 6000 m^2 site and was clad in glass and wicker. Interior materials are wicker, wood and sheetrock. Aside from the exhibition area, the pavilion also consists of reception areas, a 150 seat auditorium, a conference room and a press space. At the Expo, this Pavilion was located near to the Swiss, Polish, Belgian and French pavilions. Its free-form structure made use of a complex three-dimensional grid of tubular elements created with computer technologies. The pavilion façade was constructed from 8524 wicker panels ranging from 0.29 m^2 to 2.64 m^2, with 27 types divided by colour and shape, which provided curving support. All the wicker panels were made within three months by 40 local farmers from Chongde Village[140] in Shandong Province, China. To create a natural appearance none of the wicker panels were treated with artificial colour, and were instead, boiled in hot water for varying periods of time which created different coloured layers (Figure 2.54.). According to Sun Jianguang, who is the director of a local handicraft factory, untreated wicker is white, but the panels are boiled in hot water for 5 hours, the colour changes to brown. After 9 hours in boiling water, the colour appears as a natural black. Sun Jianguang designed four machines to enhance the efficient manufacture of the 'wicker basket', and in total,

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[138] Enric Miralles-Benedetta Tagliabue, "Spanish Pavilion for Expo Shanghai 2010," (2010).

[139] Benedetta Tagliabue was born in Milan and graduated from the University of Venice in 1989. She is the director of the Miralles-Tagliabue-EMBT studio in Barcelona, Spain. Their projects cover architectural projects, open spaces, urbanism, rehabilitation and exhibitions. Benedetta Tagliabue received The RIBA Stirling Prize in 2005.

[140] Chongde Village is located in Bo'xing Town, Binzhou City, Shandong Province, China. Bo'xing town has a 800 year history of using wicker to weave small crafts including baskets, furniture and home decorations.

120 tons of wicker was used in the manufacturing process. After Sun Jianguang and his team were introduced through the press and media, Chongde Village and the local wicker weaving skills became famous, and after careful assessment by the Ministry of Culture, Bo'xing Bian Liu (Bo'xing wicker weaving skills) was listed as part of China's National Intangible Cultural Heritage in May 2010. According to the data from the local authority, during the first five months of 2010, Bo'xing Town had exported $11,700,000 of products. With the need to plant more osier trees to enable sufficient availability of materials for the making of products to be exported worldwide, the quality of life for local farmers has improved significantly.

FIGURE 2.54. Different colour wicker panels inside the pavilion[141]

Natural fibre materials can encourage the development of the handcraft industry, thus improving the economic benefits for people who live in less developed areas, but who have great craftsmanship skills. Traditional handcraft skills can be developed to meet with contemporary demands by using natural fibre, and simultaneously protects traditional cultures for future generations.

Finnish architect and artist Marco Casagrande[142] has also used natural fibre material for small-scale constructions. In 2009, Marco Casagrande, Hsieh Ying-chun[143] and Roan

[141] Tagliabue, "Spanish Pavilion for Expo Shanghai 2010."
[142] Marco Casagrande is a Finnish architect and artist born in 1971 in Turku, Finland. He graduated from the Helsinki University of Technology Department of Architecture in 2001. He started from his early career to mix architecture with other disciplines of arts and science with a series of architectural installations around the world. He has been the Principal of the Casagrande Laboratory, an architectural studio based in Finland with collaboration internationally since 2003.
[143] Hsieh Ying-chun was born in 1954 and he is a Taiwanese architect and contractor. He was awarded the Curry Stone Design Prize 20011 to champion him as a force of social change building more than 3,000 homes with local people in natural disaster zones in both Taiwan and Mainland China.

Ching-yueh[144] designed *Bug Dome* (Figure 2.55.) for the 2009 Shenzhen & Hong Kong Bi-city Biennale of Urbanism/Architecture. The Bug Dome was built on the wasteland of an abandoned building site (3000 m^2) between the Shenzhen City Hall and an illegal workers camp. The installation was made from re-used bamboo, wood, gravel and recycled concrete. The bamboo construction techniques were based on local knowledge from rural areas in Guangxi Province, brought into the city by migrating construction workers. The space was used during the Biennale for 'underground' bands, poetry readings, karaoke and as a lounge for the illegal workers from the neighbouring camp. Once small plants began to grow on the building site, the structure was enveloped by the green environment which contrasted with the surrounding high-rise, concrete and glass buildings (Figure 2.56.). This case shows that fabric materials can be used to construct small-scale public building/structures in an urban open space to contrast with the surrounding environment in order to help raise awareness of certain issue.

FIGURE 2.55. - 2.56. Bug Dome during the 2009 Shenzhen & Hong Kong Bi-city Biennale of Urbanism/Architecture; Bug Dome "covered" in plants[145]

In 2012, Marco Casagrande designed further organic structure, *Sandworm* (Figure 2.57-2.58.), located at the dunes of the Wenduine coastline, Belgium. The structure is 45 metres in length, 10 metres in width, entirely constructed from willow, and based on the local knowledge of working with willow and sand. Casagrande organised a team of young architects and local experts who completed the structure within one month. He describes his projects as "weak architecture",[146] which he explains as "a human made

[144] Roan Ching-Yueh was born in 1958 and he is a Taiwanese architects, writer and curator. He is an Associate Professor of Department of Art Creativity and Development in Yuan Ze University located in Taoyuan, Taiwan.
[145] Casagrande Laboratory, "Bug Dome," (2009).
[146] ———, "Sandworm," http://marcocasagrande.fi/.

structure that wishes to become part of nature through flexibility and organic presence".[147] The space is a multi-functional structure used for picnics, relaxation and other social events. Unlike the Bug Dome, which acts as a contrast to its surroundings, the Sandworm has "blended" into the natural, environment of the beach and the sea.

FIGURE 2.57 - 2.58. Sandworm; Inside the Sandworm[148]

The above projects indicate that natural fabrics are reliable materials that can provide a natural aesthetic and tactile quality. In demountable building construction, other types of natural fabric materials include: ropes, textiles and straw, all of which can be used to create an organic and humane atmosphere, and to promote the use of local knowledge and technical skill in building construction.

Metals

Metals are elements made by the refinement of minerals, which each have unique qualities derived from their constituents and the processes used to produce them. Unlike wood or stone and many other materials, metals are entropic, i.e. they can be recovered, re-formed, or mixed together to form totally new metal components.[149]

Jean Prouvé[150] had a particular interest in using metals such as steel frames and aluminium to design demountable housing. Prouvé designed prefabricated demountable barracks for the French military during the Second World War.

[147] Ibid.
[148] Casagrande Laboratory, "Sandworm," (2012).
[149] Bell and Rand, *Materials for Design*: 145.
[150] Jean Prouvé (1901-1984) was born in Nancy, France in 1901. He was trained as an ironworker before he became a self-taught designer and architect.

Immediately after the war, he designed *Maison Tropicale* (1946-1949) (Figure 2.59.-2.60.), prefabricated emergency housing for the Ministry of Reconstruction and Urban Planning. These projects contain modular systems and use simple, steel frames and wooden panelling to create low-cost, lightweight structures that can be easily assembled.[151]

FIGURE 2.59 - 2.60. Jean Proivé's Maison Tropicale in New York, 2007. Photo by D. J. Huppatz; An overview of Maison Tropicale[152]

A recent example of the use of metal is *The Future Shack* (Figure 2.61.-2.62.), designed by Sean Godsell Architects. It was designed as a mass produced, re-locatable house, for emergency and relief housing. The project structure is a module that can be easily packed and transported by truck or boat within 24 hours, and it uses a steel container box (6.05×2.44×2.59m) that can be mass produced and recycled. Bell & Rand state that:

> Though the steel industry historically favours mass production, most steel elements used in building are specially fabricated as needed. Structural steels and columns are seldom mass produced despite being made using stock profile. This project, (The Future Shack), utilises mass-produced steel volumes as its basic module to achieve economies of scale that are not possible using conventional custom fabricated processes.[153]

[151] Daniel J. Huppatz, "Jean Prouve's Maison Tropicale: The Poetics of the Colonial Object In Design Issues: Volume 26, Number 4 Autumn 2010 "(2010), http://www.mitpressjournals.org/doi/abs/10.1162/DESI_a_00042.

[152] Daniel Huppatz, "Jean Prouve's Maison Tropicale in New York," in *Jean Prouve's Maison Tropicale: The Poetics of the Colonial Object in Design Issues: Volume 26, Number 4 Autumn 2010* (Massachusetts Institute of Technology Press, 2007).

[153] Bell and Rand, *Materials for Design*: 162.

FIGURE 2.61 - 2.62. The Future Shack; The interior design of The Future Shack[154]

Another project using metal as a major construction material is *The Restaurant Box* (Figure 2.63.-2.64.), designed by Swedish architecture company Tham & Videgård Arkitekter in 1999. It was designed to be a transportable, small unit, which included a compact kitchen, a bar, dish-service and a large cooled enclosure of food and beverages. The restaurant was designed to suit its environment; a business and shopping centre full of people on the move. It opens in the day time to provide a food service and closes at night, although remaining lit from inside to guide the public towards the centre's nightclubs. Construction materials include: stainless steel, aluminium, water-resistant plywood and glass. The Restaurant Box can be easily relocated and its 'open' structure can create extra spaces which allow for different customer functions. Furthermore sunlight filters through the perforated façades to create interesting and aesthetically pleasing shadows in the daytime.

FIGURE 2.63 - 2.64. The Open Restaurant Box; The Closed Restaurant Box[155]

[154] Sean Godsell Architects, "Future Shark," (1985-2001).
[155] Tham & Videgård Arkitekter, "Restaurant Box," (1999).

Apart from being used for the façades of a building, metal is a useful solid material for construction support. As such, within the Spanish Pavilion, as discussed on page 92, all the wicker covers were supported by a steel structure. The flexibility of the steel allowed the pavilion to be a 'free-form' building (Figure 2.65-2.66.).

FIGURE 2.65 - 2.66. The Model of Spanish Pavilion - Steel Structure;[156] The Model of Spanish Pavilion - Steel Structure Attached to Wicker Surface[157]

Plastics

Plastics are lightweight, resilient, generally resistant to corrosion and moisture, and can be moulded and formed into complex shapes. They have transformed almost every industry since their invention including: medicine, electronics, aeronautics, fashion, engineering, and construction. Compared to other materials, plastics have a relatively short history in building construction.[158]

Generally, plastics have characteristics as follows:

- Versatility - practically any possible shape
- Self-coloured
- Transparent or opaque as required
- Rigid or flexible as required
- Potential for different configurations
- Suitable for contemporary as well as traditional architecture.[159]

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[156] Tagliabue, "Spanish Pavilion for Expo Shanghai 2010."
[157] Ibid.
[158] Bell and Rand, *Materials for Design*: 219.
[159] British Plastics Federation RIBA Smart Material Lectures, "*Contemporary Application of Plastics in Construction*" (lecture, University of Liverpool, November 25, 2011). The lecture material is available in PDF at http://www.bpf.co.uk/.

The benefits of using plastics in building construction include:

- Strength - plastics are: durable, knock and scratch resistant, and have excellent weatherability; resistant to corrosion from water and many chemicals; tough with less leakages when used for pipes; long lasting, with windows having a lifespan of 35 years; pipes 100 years; and they experience minimal wear and tear.
- Low maintenance - plastic building products can be easily repaired and maintenance requirements, such as painting, are minimal; Use of plastics reduces the need to work at heights and minimises risk of accidents.
- Energy efficiency - providing effective installation, plastics are low conductors of heat and tight seals are achievable, thus improving energy efficiency, reducing energy bills for households and businesses, and also reducing CO_2 emissions.
- Cost effective - plastics are durable, low maintenance and labour saving.
- Ease of installation - plastics are lightweight and therefore easy to transport and carry.
- Design freedom - using plastics, most shapes are possible and can be shape-fitted to many conditions.
- Hygienic and clean - hygienic surfaces are possible with plastic due to its impermeable and washable nature and minimal joints and cracks. Plastic is therefore good for the delivery of fresh clean drinking water and often used for hospital flooring.
- Environmentally sound - plastics save resources through cost-effective production, ease of installation and long life. They can be re-used, recycled, or turned into a source of energy after use.
- Protecting the environment - 4%[160] of the world's oil is used to produce all of our plastics and, therefore, it can help preserve other natural resources.[161]

Geoffrey Broadbent argues that polythene, PVC (Polyvinyl chloride) and other sheet plastic materials are capable of space-separating functions but offer no structural support. They can, however, be used to form tents of a highly sophisticated structure by being formed into sealed enclosures which contain air, the pressure of which supports them, or by being suspended from internal or external frames.[162]

There are many demountable projects which are constructed using plastics, such as the inflatable structures, designed by Architects of Air for temporary exhibitions and social events (Figure 2.67.-2.68.). Each Luminaria is an original design and made from PVC plastics, manufactured in France especially for Architects of Air. The PVC plastics are then cut and connected in Nottingham, UK, before being transported around the world. According to *AoA Promoters Kit*, this material can function well in a wide range of weather conditions, including rain and wind, and hot, and cold temperatures. All the

[160] Other natural resources being oil consumption in other areas, such as heating and fuel.
[161] British Plastics Federation RIBA Smart Material Lectures, "*Contemporary Application of Plastics in Construction*".
[162] G. Broadbent, *Design in Architecture : Architecture and the Human Sciences* (London: Fulton, 1988), 417.

structures have been evaluated by independent structural engineers and each structure has its own Safety Dossier.[163] The structures are very easy to transport as the average size structure can be packed down into five standard pallets.

FIGURE 2.67 - 2.68. Mirazozo, Sydney, Austria, 2011;[164] Inside a Luminarium[165]

Another recent example is project; Kiss the Frog (Figure 2.69.-2.70.), designed by Architects of Norway in 2005 for The National Museum of Art, Architecture and Design in Oslo was a combined of The National Gallery, The Museum of Decorative Arts and Design, The Norwegian Museum of Architecture and The National Museum of Contemporary Art. Kiss the Frog was designed as a temporary pavilion to be used for seminars and public lectures. Similar to the Luminaria, Kiss the Frog was also based on pneumatic principles - a self-supporting construction erected by establishing a higher air pressure inside a space, defined by a membrane, than found on the outside. The membranes used for walls are opaque PVC weaves with a fire retardant layer. Different from the Luminaria which will be recycled after a period of time, Kiss the Frog was designed as a semi-permanent pavilion.[166]

[163] Architects of Air, 2011.
[164] Paul Norris, "Mirazozo-Sydney 2011," (2011).
[165] Architects of Air, "The Experience."
[166] Architects of Norway, "Kiss the Frog," http://mmw.no/projects/search/kiss-the-frog.

FIGURE 2.69 - 2.70. From left to right: "Kiss the Frog" before being inflated; "Kiss the Frog" fully inflated[167]

Glass

Glass is a hard, brittle, usually transparent, material composed of earthen elements that have been transformed by fire[168]. It is used to provide structure, enclosure, and luminance. Very few materials can perform all three of these functions simultaneously in a building.[169] In demountable buildings and especially modular buildings constructed from standard shipping containers, glass is sometimes used for decoration or for windows within a perforated facade. Glass is however, often replaced by transparent plastic due to its high cost per volume, such as in the project *Bed by Night* (Figure 2.71.-2.72.), conceived by Han Slawik in 1996 in Hanover, Germany. The original single storey building was assembled from 14 construction site containers to provide temporary accommodation and social services for street children. As part of the design, which was to be used for up to 10 years, existing containers were re-used and additional modules were added. The container ensemble, which Slawik called a "container village"[170], is housed in a protective and insulating pre-mounted industrial glass shell. Slawik placed the new, two-storey, 361 m², space on a frost-proof foundation made of large prefabricated concrete slabs, gave the wooden frame visible joints and attached

[167] Ibid.
[168] Bell and Rand, *Materials for Design*: 13.
[169] Ibid., 22.
[170] Han Slawik, *Container Atlas : A Practical Guide to Container Architecture* (Berlin: Gestalten, 2010), 162.

the glass façade via explicitly exposed fixtures to ensure that all structural components were clearly visible.[171]

FIGURE 2.71. - 2.72. From left to right: The "Container Village" with an industrial glass shell; The architectural drawing of the design[172]

Concrete

Concrete is strong when compressed, and when enhanced by steel reinforcement can also have great tensile strength. Concrete can take any shape or form through casting, and can have a variety of surface textures, finishes, and colours.[173] Concrete is not usually used as a material for demountable building design, but it can be an important foundation material. However, Georg Christian Weiss states "[concrete] buildings are often only 20 to 30 years old and the demolition is accompanied by a great quantity of dust and noise and by other restrictions for many weeks. The costs for demolition and for land-filling of building waste are very high."[174] He outlines better ways to use concrete, stating that "the structural design of concrete buildings which are demountable and use all advantages of 100% off-site prefabrication."[175] He further explains that "a prerequisite for the structural design of demountable concrete

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[171] Ibid.
[172] Urban Drift Productions Ltd, ""Bed by Night", Refuge for Homeless Children," (2002).
[173] Bell and Rand, *Materials for Design*: 53.
[174] Georg Christian Weiss, "Demountable Concrete Buildings, Structural Design of Floor Slabs with Concrete Elements and Aluminium Form" In Christian Grosse, *Advances in Construction Materials 2007* (Berlin: Springer Berlin, 2007), 698.
[175] Ibid.

structures (Figure 2.73.) must be that all joints are made in a way that the structure can be demounted without damaging of the concrete elements."[176]

FIGURE 2.73. Demountable concrete frame design[177]

The lessons learnt from examining the existing methods include:

Researchers of materials, product and construction technologies from ETH Zürich proposed a high-efficiency concrete formwork technology[178] and won the Global Holcim Innovation 1st prize[179] in 2012. The research project pursued innovatively combined existing technologies and materials - the use of re-useable and digitally fabricated wax formwork - to fabricate non-repetitive, free-form, cast-on-site, concrete structures. The whole process cycle can be presented as follows:

(i) Forming a free-form surface, by robotically forming a sand mould.
(ii) Casting (inexpensive and reusable) thermoplastic wax on the sand mould to form the formwork element.
(iii) Placing on-site of the wax formwork, onto a standardised support structure (traditional formwork elements).
(iv) Casting of the concrete against the wax formwork elements.
(v) Remove wax formwork, to be reused in new formwork elements for next project (Figure 2.74-2.76.).[180]

[176] Ibid.
[177] Georg Christian Weiss, "Demountable Concrete Frame Design," (Berlin: Springer Berlin, 2007), 698.
[178] The research groups includes: Professor Matthias Kohler, Professor Fabio Gramazio, Silvan Oesterie and Axel Vansteekiste. The estimated start of construction is January 2015.
[179] The Holcim Awards is an international competition that seeks projects and vision in sustainable construction. The Holcim Awards is conducted by the Holcim Foundation for Sustainable Construction based in Switzerland.
[180] Matthias Kohler et al., "High-efficiency Concrete Formwork Technology, Zurich, Switzerland," (2011).

FIGURE 2.74 - 2.76. Re-usable wax; Wax negative/concrete positive; 1×1 m double curved free-form wax element, produced by a robotic process, and the concrete positive cast against it[181]

Different from subtractive fabrication methods,[182] the proposed innovative fabrication methods result in a less wasteful process cycle. The wax form work can be dismantled and re-used in an ecologically sustainable approach. The proposed scheme is important for establishing a precise, economic and resource-efficient technique for the fabrication of free-form concrete structures, especially for highly industrialised, high-density countries such as China and India. The project is currently only at the conceptual stage, but it has potential for application on a larger scale in the future. However, this method suggests that there is a huge potential in using concrete as a stable and sustainable material for future demountable constructions, although further empirical research is to be carried out in this area.

Other Materials

As shown above, wood, bamboo, paper, cardboard, natural fibre, metals, and plastics are commonly used materials for demountable buildings or structures, with glass and concrete being used, less frequently). There are many other materials which can be used in demountable buildings, either for structural frames or building façades, or both. These include a variety of man-made and natural materials, such as mirrors, gabions (stones) and snow.

[181] Matthias Kohler et al., "High-efficiency Concrete Formwork Technology," (2011).
[182] Subtractive fabrication indicates the manufacturing of products by machine tools that reduce a solid block of metal or other material by any combination of drilling, turning on a lathe and grinding. The opposite term is *additive fabrication* that means manufacturing products by building them one small layer at a time.

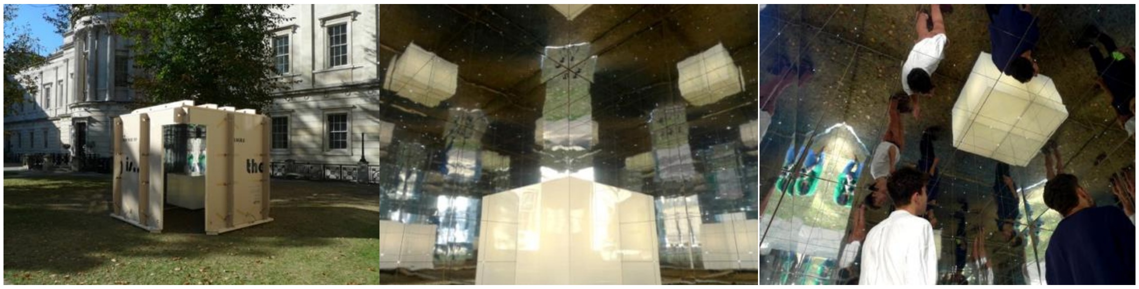

FIGURE 2.77 - 2.79. The Portable Gallery; Inside the Portable Gallery; The reflective roof inside the Gallery[183]

An example of this is the *Portable Gallery*, (Figure 2.77.-2.79.) which was designed by Mobile Studio for UCL Museums & Collections in 2011. The project aim was the use of a series of demountable components (for easy installation) to host a number of public events for the Museum's outreach programme. The gallery was 2.2 metres in length, width and height, and was designed to accommodate up to three visitors at one time with just one museum artefact on display. It was constructed from composite, lightweight, recycled paper and honey-comb panels which were laminated with a tiled mirror finish on the internal surfaces. The mirrored effect allowed visitors to see all sides of the museum object in the reflection of the gallery walls, with the object being multiplied infinitely within the limited space.[184] As such, a reflective material can be used to create the illusion of a much larger interior space than the space in actuality.

A further example of the use of natural materials in demountable construction is the use of gabions (Figure 2.80-2.81.), or "caged rocks".[185] Gabions can "capture the feel of non-linearity, and essential characteristics of beauty in nature"[186]. A gabion is typically a wire or fabric container, uniformly partitioned, and of variable size, interconnected with other similar containers and filled with stones. Gabions are often used to form flexible, permeable, monolithic structures such as retaining walls, sea walks, channel linings, revetments and weirs for erosion and flood control. The earliest known use of gabion-type structures was for along the banks of the Nile River protection about 7,000 years ago. Since then, gabions have developed from "baskets of woven reeds"[187] to

[183] Mobile Studio, "Portable Gallery," (2011).
[184] Ibid., 2011.
[185] Ian Ritchie Architects, "Gabion," http://www.ianritchiearchitects.co.uk/innovation/gabion/.
[186] Ibid.
[187] Ibid.

"engineered containers manufactured from mesh",[188] and due to its inherent flexibility, and ease of transportation, the gabion system can be seen as demountable.

FIGURE 2.80 - 2.81. Gabion test assembly, London Regatta Centre;[189] Gabion load testing, Turin[190]

Evidence shows that timber has also been used to construct gabion systems, such as the *Gulpwald Willisau Forest Pavilion* (Figure 2.82-2.83.), designed by CAS Architekten[191] in 2003 for the 700th anniversary of the district of Willisau in the Lucerne canton of Switzerland. The pavilion provided an open meeting space where indoor and outdoor areas were combined, and the walls used to define the spaces were gabion systems constructed from steel and timber.

FIGURE 2.82 - 2.83. Waldpavilion Gulpwald, Willisau; Gabion walls constructed from steel and woods[192]

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188 Ibid.
189 Ian Ritchie Architects, "Gabion test assembly, London Regatta Centre," (1997).
190 Ian Ritchie Architects, "Gabion load testing, Turin," (1992).
191 CAS Architeken is an architecture company based in Luzern, Switzerland.
192 CAS Architekten, "Waldpavillon Gulpwald, Willisau," (2003).

Gabion walls are widely used in landscape design. Artists from Cuckoo Farm Studios[193] have discovered an innovative way of building garden gabions from small, colourful, recycled, materials (Figure 2.84.). Gabion systems have great potential in the construction of small-scale demountable structures as they can accommodate aesthetic needs as well as functional needs.

FIGURE 2.84. Gabion wall[194]

Whilst the materials discussed above, stay in the same physical state after being dismantled, there is one natural material, snow, transfers from a solid state into a liquid state once demolished. One extraordinary project which uses snow as a construction material is the *Icehotel* (Figure 2.85.-2.88.), a hotel built of snow and ice in the village of Jukkasjärvi in Sweden, 200 kilometres above the Arctic Circle. Yngve Begkvist is the founder of Icehotel, and the Icehotel Art and Design Group first started working in the 1970's under the direction of the Local Folklore Society in Jukkasjärvi. In mid-November, when winter falls, a team of architects, designers, artists and snow builders gather to create each year's unique Icehotel, - a hotel with 47 rooms (2011/2012)[195] made from snow.

[193] Cuckoo Farm Studios was formed in 1992 in converted farm buildings on the northern outskirts of the historical town of Colchester. The Studio has been developed as a valuable resource within the wider community through collaborative links with Colchester School of Arts and Design and Essex University. They support students through their Graduate Award Scheme and advance artists through professional development.
[194] Cuckoo Farm Studio, "Gabion Wall," (2008).
[195] ICEHOTEL, "How We Build ICEHOTEL," http://www.icehotel.se/uk/ICEHOTEL/About-ICEHOTEL/How-we-build-ICEHOTEL/.

FIGURE 2.85 - 2.88. Snow gun making snow; Snow on the steel forms; Transporting ice-blocks;[196] Art Suite 302[197]

The huge amount 'material' required is made by snow guns and ice-blocks that are harvested from the nearby Torne River. Snow is sprayed onto large steel forms and allowed to freeze. After the snow has set, the forms are removed, leaving freestanding corridors of snow. Small cracks in the corridors are common but soft snow is carefully pushed into the gaps. Large ice-blocks are transported into the hotel from which artists create the different hotel suites. The construction of the Icehotel is completed in several phases by a group of people with different areas of expertise. Once one section is completed, it opens to visitors despite other sections still being under construction. After the Icehotel is dismantled, the snow blocks melt into the waters of the Torne River, and whilst the snow will not be exactly the same again, the material will always be collected from the same source.

With a longer history of using ice for temporary construction, the annual Harbin International Ice and Snow Sculpture Festival has been held since 1963. Harbin is located in Northeast China where, the winter winds from Siberia, the lowest temperature can reach -35°C. The festival generally opens on 5 January to the public and lasts for one month, although it can open earlier and last longer, weather permitting. Ice blocks are collected from the frozen Songhua River, which is the largest

[196] ICEHOTEL, "Building ICEHOTEL."
[197] The Art Suite 302 is designed by Natsuki Saito & Shingo Saito, Japan. ICEHOTEL, "Bedtime Story."

tributary of the Heilong River. 'Buildings' are constructed with fluorescent lights encased in these ice blocks, turning the 'ice city' into a night time wonderland.

FIGURE 2.89 - 2.91. An overview of the temporary "ice building";[198] Festival visitors enjoy an ice slide;[199] An ice labyrinth[200]

Every year, the large ice and snow sculptures add a beautiful ephemeral image to the city's skyline (Figure 2.89.), although some of the structures also satisfy functional needs such as an ice slide (Figure 2. 90.), an ice bridge or an ice labyrinth (Figure 2. 91.). Visitors come to view the constructions and illumination, as well as for winter sports; including skiing, sledding and even ice swimming.

Both the Icehotel and the Harbin International Ice and Snow Sculpture Festival have presented incredible structures made from inherently sustainable materials - ice and snow. They are completely demountable and succeed in creating unique experiences from seasonal materials. These qualities, and the temporary nature of the material, has led to both the Icehotel and the Ice and Snow Sculpture Festival receiving great attention from the public. The temporality attracts visitors who do not want to miss each year's new design, and demountable buildings can be similarly advertised to maximise reference to their temporary nature as a limited 'window of opportunity'. However, to investigate this, evaluation methods are required to research in what circumstance an exhibition or an event hosted within a demountable building can receive more positive feedback from its visitors than a comparable event in a conventional building.

[198] Jonathan Browning, "Winter's Palace," (2012).
[199] Ibid.
[200] Ibid.

2.3.4.2.4 Colour

The colour of an object is perceived before the finer details (of its shapes and lines). Colour is a sensation of light that is transmitted to the brain through the eye, and it has been shown to affect human moods, physiological responses, and perceptions of temperature, size and ambiance. As with colour in conventional buildings, a user's understanding of colour in demountable buildings is affected by many factors.

(i) Culture - colours have been used symbolically in many ways. Memory, experiences, and cultural background all affect the way colour impacts upon an individual. This means that colour is physically perceived the same way but can mean different things to different people. A typical example can be seen in most Western cultures where a bride usually wears a white wedding dress to symbolise purity. In traditional Chinese culture, however, white is regarded as a symbol of death and would not, therefore, be worn at a wedding. The challenge of using colour in demountable building design is that designers often need to make sure the colour of a building can be accepted in different locations by different groups of visitors.

(ii) Façade patterns - the more that a surface is broken up, the smaller it will appear. Smooth, flat surfaces appear to be larger. Colour usage can, however, reverse this effect and a building containing many windows set into a white grid or surface will appear to be smaller than a building that is the same size but has blue-tinted windows set into a steel grid or surface.

(iii) Light and weather conditions - light and artificial lighting systems directly affect the colour of a building, especially in the evening. These can create many different colour schemes according to requirements. Further, weather conditions can have a strong influence on the perception of a building by its visitors and Edith Anderson Feisner states "[i]t must be noted that architectural colour is often impermanent. It changes because of weathering and staining of materials."[201]

(iv) Materials – in demountable building designs, because they often use many unusual materials for construction, every material can provide a unique

[201] Edith Anderson Feisner, *Colour : How to Use Colour in Art and Design* (London: Laurence King, 2006), 145.

colour to the building. For example, unpainted paper tubes give a natural beige colour, whilst bamboo tubes are naturally yellow green.

(v) Surroundings - colours within the surroundings/environment will affect the responses to buildings. This raises the question of how one demountable building design can fit successfully into different built environments. In order to answer this question, when Zaha Hadid Architects designed the Chanel Mobile Pavilion, they used fibre reinforced polymer (FRP)[202] for the façade, a reflective material that allows the exterior surface of the building to be illuminated according to the local surroundings and events.

(vi) Texture - surface textures of a demountable building affect how it and its colour are perceived. The rougher a surface is, the darker it will appear to be. The smoother a surface is, the lighter it appears.

(vii) Use of contrast – this affects architectural perception, with light and dark contrasts creating three-dimensional effects where none exist. Warm and cold colours express different emotions (this, as contrast is the same with static building).

2.3.4.2.5 Illumination

Illumination is the combination of colour and light. Le Corbusier states "Architecture is the learned game, correct and magnificent, of forms assembled in light."[203] Mary Ann Steane writes that, in Le Corbusier's early distillation of the design principles of modernism, two different perspectives on light emerge. The first of these concentrates on architecture as an illuminated object viewed statically at a distance.[204]

She also quotes Louis Kahn's explanation as to why architects should always be looking to exploit natural light:

> All spaces need natural light. That is because the moods which are created by the time of the day and seasons of the year are constantly

[202] Stage One Creative Services Limited is based in York, UK, and has delivered Chanel Mobile Pavilion's structure and materials.
[203] Le Corbusier, Vers Une Architecture, quoted in Mary Ann Steane, *The Architecture of Light : Recent Approaches to Designing with Natural Light* (Abingdon, Oxon; New York: Routledge, 2011), 11.
[204] Ibid.

> helping you in evoking what a space can be if it has natural light and can't be if it doesn't. Artificial light is a single tiny static moment in light and can never equal the nuances of mood created by the time of day and the wonder of the seasons.[205]

Artificial lighting is also important to the illumination of a demountable building. Alan R. G. Isaac summarises that a poorly illuminated element may attract interest and become dominant if it is set in a highly illuminated enclosure. A well-illuminated element will generally dominate the total enclosure if it is positioned in a dark surround. Colourful lighting systems can also be used to aid the illusion.[206]

According to J.J.H. Lau's research into the assessment of lighting quality, "as illumination increases, the room becomes more 'pleasant', but beyond a certain point, further increases in illumination result in a decrease in 'pleasantness'." [207] Lau's hypothesises that "it may be due to the observers' optimising between what may be an acceptable level of illumination and level of acceptable discomfort glare. For each lighting arrangement, as illumination increases, so does source luminance, thus the interaction."[208] Due to the variety of the materials which can be applied to demountable buildings, the texture of the selected material can create many different illumination effects.

2.3.4.3 Acceptability to the Users

The assessment of 'building friendliness' is decided by its acceptability to the users, which means how well the design of the building is accepted by people psychologically. Generally, architects have tools (simulation software, monitoring equipment) to measure the physical performance of buildings. However, there are no 'tools' to measure 'building friendliness'. This 'friendliness' can instead be measured through psychological experiments.[209]

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[205] Jean France, Louis Kahn's First Unitarian Church, quoted in ibid., 7.
[206] Isaac, *Approach to Architectural Design*: 53-54.
[207] J.J.H.Lau, "Differences between Full-Size and Scale-model Room in the Assessment in the Assessment of Lighting Quality" In David V. Canter, Strathclyde University of, and Architects Royal Institute of British, "Architectural Psychology : Proceedings of the Conference Held at Dalandhui, University of Strathclyde, 28 February-2 March 1969" (London, 1970), 43.
[208] Ibid.
[209] More information on accessibility in architectural design can be found in the 2012 edition of *Designing for Accessibility*, the most up-to-date guidance that assists architects and designers in designing public buildings and outdoor space.

Acceptability to users leads to their satisfaction, which means that if the functions of the building are acceptable, then it is pleasant to use the building. 'Satisfaction of users' has been used as an indicator of a building's serviceability, and of when to give priority to resolving problems within it. Many large corporations and government providers of facilities use Satisfaction Surveys as part of their facility management toolkit. For instance, for some years the US General Services Administration (GSA), the provider and facility manager of offices for the US government, conducted a comprehensive user satisfaction survey of all the offices it provided. It adapted a survey developed for the International Facility Management Association and set a target level for occupant satisfaction. The GSA found that occupant satisfaction was not actually revealing it which building should be prioritised for repairs because of two intervening variables. Firstly, occupant satisfaction was dominated by the perceived responsiveness and helpfulness of the personnel providing the facility management, rather than by the serviceability of the physical building. Secondly, respondents mistakenly thought that facility administrators in their own units, to whom they took their complaints, were the facility managers, rather than the GSA staff who actually managed their buildings.[210]

Some lessons can be learnt from this case:

(i) 'Building friendliness' is partly determined by how well the activities in this building are organised. Although this is generally beyond the measurement of the architect or designer, a good design should enable organisers to effectively operate their events inside the building, thereby helping to offer visitors a pleasant building experience.

(ii) Different to the GSA case, the user time in a demountable building is typically shorter than in a static building. It might be difficult to receive effective feedback from users because they may need a longer building experience time to establish potential problems.

(iii) Demountable buildings often face varying user groups. The cultural differences of users can lead to a building being accepted in one location but not accepted in another.

[210] International Standards Office, "ISO 11863:2011 (E), Building and Building-Related Facilities - Functional and User Requirements and Performance - Tools for Assessment and Comparison," 12.

2.3.4.4 Appropriateness at Building Sites

Most demountable buildings are temporarily constructed within a permanent site. Generally, they are built in open spaces with easy access, such as parks, squares, car parks, harbours and, sometimes, inside a large building. James A. LaGro identifies three types of open space as: conservation open space; developed "hard" open space; and developed "soft" open space.[211] Conservation open space generally means green land, whereby it is a natural environment which provides an organic aesthetic amenity impression for visitors. Developed "hard" open spaces (e.g. plaza, promenade or courtyard) and developed "soft" open spaces (e.g. lawn, garden or park) are built environments.

TABLE 2.5. Open Space Types Summarised by James A. LaGro[212]

Open Space Types		
Conservation open space	Developed "hard" open space	Developed "soft" open space
Woodland	Plaza	Lawn
Grassland	Promenade	Garden
Water	Courtyard	Park

Apart from open spaces, there are also small, relatively restricted, informal spaces in urban areas which can be used to construct small-scale demountable buildings. In Tokyo, for example, architect Yoshiharu Tsukamoto[213] found that there are small buildings, between streets, along widened roads, and in the spaces between tracks and streets. Most of these buildings are built at a low cost, are not spectacular in design, and have not required cutting-edge technology. Tsukamoto called these buildings "pet architecture",[214] and much of it is built as small retail, hairdressing and property agencies. Some 'pet architecture' is entirely demountable and its temporary existence became a tool for Tsukamoto to use to explore how towns and cities have been developed through time.

Apart from open space and informal space, another key fact regarding the sites of demountable buildings is that heavy foundations are often not required due to the light

[211] James A. LaGro, *Site Analysis : A Contextual Approach to Sustainable Land Planning and Site Design* (Hoboken, N.J.: John Wiley & Sons, 2008), 265.
[212] Ibid.
[213] Yoshiharu Tsukamoto was born in 1965 in Kanagawa, Japan. He established Atelier Bow-Wow—a Tokyo-based architecture firm in 1992 with Momoya Kajima. Their work is well known for its domestic and cultural architecture and research in urban conditions of micro architecture in Japan.
[214] Different from Yoshiharu Tsukamoto's artistic name of "pet architecture", the same type of buildings is referred to as "unapproved construction projects" in China.

weight nature of many demountable buildings.[215] Furthermore, demountable buildings can be surrounded by the natural environment, built environment or both. The existing environment provides standards for designing new buildings and sites in the vicinity. Contextual issues concern material choices, as well as the size and proportion of buildings. A well-chosen open space can strengthen a demountable building's identity and provide additional value, by being a pleasant environment conducive to more active activities. The arrangement and positioning of a demountable building not only depends on the availability of the construction space, but also on the position of the surrounding existing buildings. The key relationship between a demountable building and its static background is that the users are aware of the temporality of the demountable building and the motionless of its background. As such, the users create the criteria of how well the demountable building is perceived, and this indicates the importance of users' opinions to this research.

2.4 Analysing the Relationships between Public Demountable Buildings and Sites through Selected Examples

Broadbent states, in *Design in Architecture* that "one needs three kinds of information in order to design a building; concerning the pattern of activities which it is to house, the available site with its indigenous climates, and the technology of building available for reconciling the two."[216] Based on T.L. Markus's Building-Environment-Activity-Objectives model, Broadbent developed a conceptual model in which three major systems - human, building and environment - are interrelated.

[215] Some small-scale demountable buildings require a concrete foundation.
[216] Broadbent, *Design in Architecture : Architecture and the Human Sciences*: 384.

TABLE 2.6. Interrelations in Building Design, G. H. Broadbent, adapted from T. L. Markus: Building-Environment-Activity-Objectives model[217]

INTERRELATIONS IN BUILDING DESIGN

Environment System		**Building System**		**Human System**	
Cultural Context	***Physical Context***	***Building Technology***	***Internal Ambience***	***User Requirements***	***Client Objectives***
Social Political Economic Scientific Technological Historical Aesthetic Religious	The site as given in terms of: Physical characteristics: climatic geological topographical Other constraints: Land use existing built forms, traffic patterns, legal	Modification of external environment to provide suitable ambience for specified activities by means of : Available resources in terms of: Cash Materials Labour/equipment Structural systems: Mass Planar Frame Space separating systems: Mass Planar Frame Services system: Environmental Information Transportation Fitting system: Furnishing Equipment	Provision of physical conditions for performance of activities in terms of: Structural mass: Visible surfaces Space enclosed Sensory environment: Lighting Sound control Heating/vent	Provide for specified activities in terms of the following needs: Organic: Hunger and thirst Respiration Elimination Activity rest Spatial: Functional (inc. fittings) Territorial Location: Static, dynamic Sensory: Sight Hearing Heat and cold Smell Kinaesthetic Equilibrium Social: Privacy Contact	Return for investment in terms of: Security Prestige Profit Expansion or Other provision for change Housing of particular activities so as to encourage user; Well-being, motivation, etc.

The following sections will select a series of contemporary demountable building examples to analyse the relationships between public demountable buildings and their sites.

[217] T. L. Markus, Interrelations in Building Design, quoted in ibid., 385.

2.4.1 Projects Deployed in a Single Location

In this section, the key characteristics of demountable buildings that are completely dismantled after use and are not assembled again as the same building, will be discussed. Parts of these buildings can be recycled or re-used for other purposes in the manufacturing industry.

2.4.1.2 The Model of San Carlo alle Quattro Fontane[218]

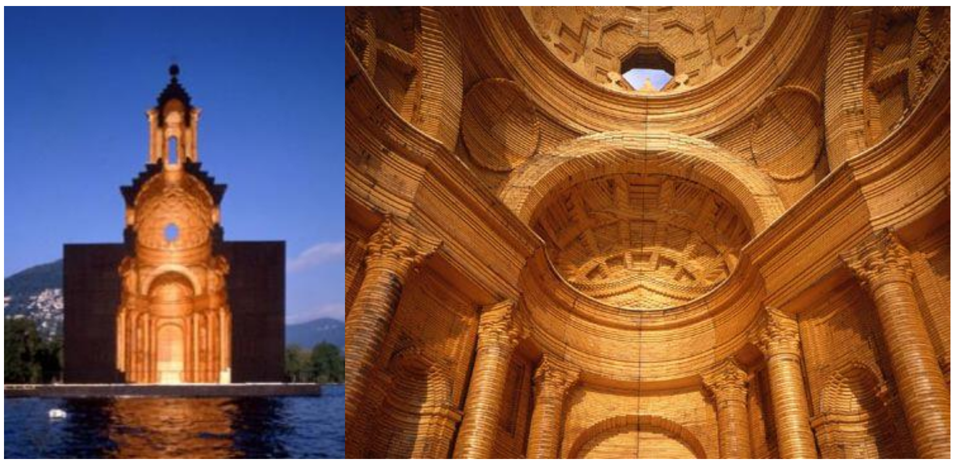

FIGURE 2.92 - 2.93. Wooden Model of Borromini's Church of San Carlo alle Quattro Fontane in Rome on The Lakeshore Lugano, Switzerland; Inside the Wooden Model[219]

To celebrate the 400th anniversary of the birth of architect Francesco Borrimini (1599-1667), Swiss architect Mario Botta[220] designed the *Wooden Model of San Carlo alle Quattro Fontane* for the exhibition at the Museo Cantonale d'Arte in Lugano, Switzerland (Figure 2.92.-2.93.). The full-scale wooden model was 33 metres high and it was set on a 22 m^2 platform anchored a few metres from the shore of the Lugano lake, near to the entrance of Parco Ciani.[221] The model was constructed from 35,000 planks 4.5 cm thickness. Steel cables held the planks together and the whole structure was attached to a 100-ton steel frame.[222] The project team involved 200 people working together, including architects, designers, carpenters, craftsmen, graphic designers and

[218] The Church of Saint Charles at the Four Fountains is a Roman Catholic Church in Rome designed by Francesco Borromini.
[219] Mario Botta Architetto, "Wooden Model of Borromini's Church of San Carlo alle Quattro Fontane in Rome on The Lakeshore Lugano, Switzerland; Inside the Wooden Model," (1999).
[220] Mario Botta was born in 1943. He is a Swiss architect who studied in Milan and Venice.
[221] Parco Ciani is a park in Switzerland.
[222] Philip Jodidio and Karin Haag, *Architecture Now!* (Köln [u.a.]: Taschen, 2005), 52.

unemployed people. The construction assembly started on site in January 1999 and was completed in August the same year. The project was a popular tourist attraction in Lugano at the time and was dismantled in 2003. This structure was not only a tribute to Borromini, but also presented a modern understanding of Baroque architecture through a geometric and mathematical concept. It was surrounded by a combination of the natural and built environment, including lake, mountains and trees, and houses and small boats. The selected location enhanced the Wooden Model's identity and offered a pleasant environment. At the same time, the model itself provided additional value to the selected location such as attracting tourists and promoting interactions between the local and the visitor.

2.4.1.3 Westborough Primary School Cardboard Building

FIGURE 2.94. Westborough Primary School Cardboard Building[223]

This cardboard primary school building in Kent (Figure 2.94.) was designed by Cottrell and Vermeulen Architecture and constructed under the guidance of Buro Happold[224] from 1999-2002. According to the information provided by Cottrell and Vermeulen

[223] Conttrell and Vermeulen Architecture, "Westborough Primary School Cardboard Building," (2002).
[224] Buro Happold is a professional services firm providing engineering consultancy, design, planning, project management and consulting services for all aspects of buildings, environment and infrastructure. The firm was founded by Sir Edmund Happold in 1976. Buro Happold currently has 27 offices around the world, with its head office in Bath. Sir Edmund Happold (1930-12th January 1996), was a British structural engineer who was educated in Civil Engineering at University of Leeds. He collaborated with Frei Otto, setting up a laboratory to study lightweight tensile structures with William Ian Liddell, Vera Straka, Peter Rice and Michael Dickson.

Architecture, the building is the first permanent cardboard building in Europe.[225] The building was a research project carried out as a collaboration between architects, the children and staff at Westborough Primary School, the Cory Environment Trust, and the Department of Environment, Transport and Roads. The project team included engineering consultants Buro Happold, contractor CG Franklin Building Ltd and three cardboard manufacturers. The design of was inspired by the strength of folded paper structures and origami. Apart from providing a friendly and functional environment for the school children, it aimed to use 90% recycled materials in construction. All the panels were prefabricated off-site. The walls and roof are 166 mm thick, timber-edged insulated panels made of layers of laminated cardboard sheet and cardboard honeycomb. Recycled interior products included rubber floor tiles, wastepaper structural board, polyurethane core board, pin board, and Tetra Pak board. Most of the materials will be recycled at the end of its estimated 20-year life. Many of the structural materials have good acoustic and insulation values.[226]

A key feature of Westborough Primary School is that it is a permanent (estimated 20-year), rather than a temporary demountable building. It highlights important issues regarding the optimum way of utilising demountable buildings efficiently and raises the question of whether it is best to dismantle demountable buildings and transport them to different sites or recycle the building's components. Immediate dismantling is often not the best option for project owners, and depends upon budget, timescale, the quality of the building and many other features. Consequently, it is important for project owners to evaluate the project before it is dismantled, classify a list of priorities and to identify the alternatives.

Westborough Primary School is a research project between the architects, the school's children and its teaching staff. This is a good example of the author's previous assumption that small-scale demountable buildings can encourage design innovation by being opportunities for experimentation.

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[225] Conttrell and Vermeulen Architecture, "Westborough Primary School Cardboard Building," http://www.cv-arch.co.uk/.
[226] Alastair Fuad-Luke, *The Eco-Design Handbook : A Complete Sourcebook for the Home and Office* (London: Thames & Hudson, 2009), 232.

2.4.1.4 The Prada Transformer

FIGURE 2.95 - 2.96. Rotating Prada Transformer;[227] Prada Transformer outside The Gyepnghui Palace[228]

The Prada Transformer (Figure 2.95.-2.96.) was designed by Rem Koolhaas to host Prada fashion events in Seoul, South Korea and was located near the 16th Century Gyepnghui Palace. The installation was tetrahedron-shaped, with four floor plans, (hexagon, rectangle, cruciform and circle), and events included fashion displays, film showings, art exhibitions and special events. The concept was that "when the building flips over, each side takes on different functions: floors become walls, walls become ceiling and so on".[229] By rotation, its base and walls created different forms and enabled it to become four different venue experiences for its users.

The Prada Transformer was constructed using a steel frame which was then covered by a PVC skin, similar in type to that used for jet liners and large machinery. The skin's translucent quality allowed pale light to enter the structure. It had 1600 m^2 of surface area when completed and appeared, due to the manufacturing and installation process, to be a single giant piece. All safety regulations had to be adhered to, which resulted in the material being pliable, fire- and waterproof. Once the membrane skin had been placed over the steel structure, extra spray was then applied to the surface which gave it more strength and tautness. The skin was so resilient that it remained attached even during the rotation, and essential to this process was that the space between the four plans was used by rotating the entire structure through a repeating series of regular

[227] Prada Spa, "Prada Transformer Art," (2009).
[228] ———, "Prada Transformer Waist Down," (2009).
[229] ———, "Prada Transformer Project," (2009).

movements (rotate 60°, flip, down and up) using cranes. This project is a good example of how limited space can be maximised by applying flexible design.

2.4.1.5 The Norway Pavilion at Shanghai Expo

FIGURE 2.97. A relocated "tree" after Expo[230]

The Shanghai Expo opened on 1 May and closed on 31 October 2010. The Expo authority reported that 73 million people visited the 5.28 km² exhibition site, which included 246 participants, including countries, companies and NGOs. The Norway Pavilion[231] was a 2800 m² exhibition pavilion built in 140 days. The theme of the Expo was 'Better City, Better Life', and The Norway Pavilion was to represent a sustainable urban development for the future. Its key aim was to extend the life of the pavilion through after-use whilst at the same time representing Norway in the World Expo. Following research into culture and technology, Helen & Hard Architects proposed designs for a field of 'trees' to represent Norway. These 'trees' could be easily erected, dismantled and transformed. During the exhibition, they were assembled into a sensory and multifunctional 'forest', and after the exhibition, each tree could be re-used as a public installation or otherwise (Figure 2.97). The pavilion was made up of 15 'trees', each of them a functional part of the whole pavilion and influenced both from a top-down and a bottom-up design approach. Each 'tree' was made of a laminated timber construction with four CNC (Computer Numerical Control) cut and milled branches, one trunk and four 'roots' serving as foundations. The primary structure was transported from Norway and the

[230] Helen & Hard Architects, "Norway Pavilion, Expo Shanghai," (2010).
[231] Images are available on page 82.

rest of the materials were from China.[232] After the exhibition, the pavilion was dismantled and the components prepared for other uses such as small playground equipment, furniture or meeting places.

2.4.2 Projects Deployed in Multiple Locations

In this section, the key characterises of demountable buildings which are designed to be completely or partly dismantled after use and assembled again as the same building at a different site, will be presented.

2.4.2.2 The Nomadic Museum

FIGURE 2.98 - 2.100. The Nomadic Museum in New York;[233] The Nomadic Museum in Santa Monica;[234] The Nomadic Museum in Tokyo[235]

The *Nomadic Museum* (Figure. 2.98.-2.100.) was designed by Shigeru Ban Architects with the consultation on structural engineering from Buro Happld. It was designed for Ashes and Snow, a large-scale exhibition of photographic artworks and films produced by Canadian-born photographer and filmmaker Gregory Colbert living in Paris. The Nomadic Museum is the “permanent travelling home”[236] of Ashes and Snow. The first

[232] Helen & Hard Architects, "Norway Pavilion, Expo Shanghai," http://www.hha.no/projects/norway_pavilion/.
[233] Shigeru Ban Architects, "Nomadic Museum-New York, USA," (2005).
[234] ———, "Nomadic Museum Santa Monica-Los Angeles, USA," (2006).
[235] Gregory Colbert, "Exhibition-The Nomadic Museum-Ashes and Snow," (2007).
[236] Ashes and Snow, "The Nomadic Museum," http://www.ashesandsnow.org/en/exhibition/nomadic-museum.php.

design was led by Ban and involves two of his favourite construction elements - structural paper tubes and used shipping containers.[237]

TABLE 2.7. A Selection of the Measurements of The Nomadic Museum in New York, Santa Monica, Tokyo[238]

	New York	Santa Monica	Tokyo
Site area (m^2)	5574	6770	8587.79
Building area (m^2)	4180	5574	5317.75
Total Floor area (m^2)	3020	5574	4746.33
Number of containers	148	152	152

The journey of the Nomadic Museum began in New York, from March to June 2005, where its site area (Pier 54 on Manhattan's Lower West Side) was long and narrow in shape. In 2006, when the exhibition was presented in Santa Monica near Los Angeles, the site was shorter and much wider. To accommodate this, the original 200m long gallery was divided into two 100m lengths which were arranged parallel to each other with a space between them of the same width as the gallery. This double structure used the same technology and typology as the single-frame building erected in New York. In Santa Monica, however, a membrane roof was put over the void between them and a museum shop and cinema were added by a request from the artist. In this way, it was possible to increase functionality whilst avoiding increasing the number of containers. In Tokyo, the structure was again erected in two lengths due to the construction site. Philip Jodidio states: "this type of design is very much at ease at the limits of an urban area, in a parking lot, or on a dock. Its configuration can be changed, but the idea remains the same."[239] Using local materials was one of the key strengths of the Nomadic Museum and it was well suited to New York, Santa Monica and Tokyo's coastal city locations. Distinct spaces were created according to each local building site by arranging the shipping containers differently. Each exhibition was temporary, but the concept of the Nomadic Museum being a travelling museum, is permanent.

[237] Philip Jodidio and Shigeru Ban, *Shigeru Ban : Complete Works, 1985-2010* (Köln: Taschen, 2010), 377.
[238] Ibid.
[239] Ibid.

2.4.2.3 The Paper Church

FIGURE 2.101 – Figure 2.103. The Paper Church in Kobe; Inside the Paper Church in Kobe;[240] The Paper Church in Taiwan[241]

There are many other great examples of projects deployed in multiple locations, one of which is the *Paper Church* (Figure 2.101.-2.103.) designed by Ban between March and July 1995 to replace the former Takatori Church destroyed during the Great Hanshin-Awaji Earthquake which had struck Kobe and its surrounding areas in Japan in January that year. The Paper Church was constructed from 58 paper tubes (330 mm in diameter, 15 mm thick and 5 metres high[242]) with corrugated polycarbonate sheeting used as a skin. Although all the construction materials had transient characteristics, the church was not disassembled until June 2005.[243] After the church community decided to build a new permanent Takatori Church, the Paper Church was dismantled and shipped to Taiwan as a donation to a Catholic community whom had suffered from the devastating 921 Earthquake of 1999. It was rebuilt in Taiwan in 2008.

The Paper Church, in terms of material, scale and construction methods, remained the same design, with only its environment, location and users changing. Although it was designed as a temporary church, its current destination is likely to see it as a permanent place of worship. Ban said in an interview with Douglas Murphy[244] in 2011:

> There is no difference between temporary and permanent…If a concrete building is made by the developer just to make money, it is always temporary because another developer will destroy it to build a new one. That's a huge waste. Temporary is not because of the structure. Temporary is just the purpose of the building.[245]

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240 Shigeru Ban Architects, "Paper Church-Kobe, Japan, 1995-2005 (disassembled)," (1995).
241 ———, "Paper Dome Taiwan-Taiwan," (2008).
242 Ban et al., *Shigeru Ban : Paper in Architecture*: 54.
243 Jodidio and Ban, *Shigeru Ban : Complete Works, 1985-2010*: 175.
244 Douglas Murphy is based in London. He describes himself as a writer, architects, academic and musician. He is an 'Architecture Correspondent' for the Icon Magazine.
245 Douglas, Murphy, "Cardboard Citizen," *Icon International Design, Architecture & Culture*, November 2011, 90-91.

Ban’s explanation of temporary and permanent helps to answer the question of why some demountable building projects are deployed in a single location and some are deployed in multiple locations. The ‘purpose’ includes the design objectives - what the design intends to achieve in both the short and longer term. To this end, practical evaluation criteria can be used by project owners to decide whether to dismantle the building after exhibition or use it again in the future.

2.4.2.4 Chanel Mobile Pavilion

FIGURE 2.104 - 2.107. From left to right: Chanel Mobile Pavilion in Hong Kong;[246] Chanel Mobile Pavilion in Tokyo;[247] Chanel Mobile Pavilion in New York;[248] Chanel Mobile Pavilion in Paris[249]

Another recent example of a project deployed in multiple locations is the *Chanel Mobile Pavilion* (Figure 2.104.-2.107) designed by Zaha Hadid Architects. It was constructed using steel as its primary structure, aluminium extrusions as a secondary structure, fibre reinforced plastic for façades and PVC for the roof. Its completed area is 700 m^2.

The pavilion was first exhibited in Hong Kong in February 2008 before being packed into 55 shipping containers and travelling to Tokyo. After Tokyo, it was located in New York Central Park in July 2010[250]. In March, 2011, the pavilion reached its final destination outside the Institut du Monde Arabe[251] in Paris. It was donated by Chanel for the institute to exhibit works of designers, artists and architects from Arabic countries. Similar to the Paper Church, the Chanel Mobile Pavilion was designed as a building for temporary events, but became a permanent venue at the end of its nomadic lifespan.

[246] Virgile Simon Bertrand, "Mobile Art Chanel Contemporary Art Container," (2008).
[247] Toshio Kaneko, "Mobile Art Chanel Contemporary Art Container," (2008).
[248] John Linden, "Mobile Art Chanel Contemporary Art Container," (2008).
[249] François Lacour, "Chanel Mobile Pavilion, Paris," (2011).
[250] *The Charlie Martinez Blog*; “The Chanel Pavilion @ Central Park,” blog entry by Junjie Xi, November 5, 2010.
[251] The Institut du Monde Arabe is also called Arab World Institute. It was established in 1980 in Paris. It aims to disseminate information about the Arab World and contribute to the development of the relationships between Arab World and Europe.

Hadid writes that: "reflective materials allow the exterior skin to be illuminated with varying colours which can be tailored to the differing programmes of special events in each city."[252] As previously discussed, reflective materials have been used for interior design, creating an illusion of a larger interior space than the actual space. The Chanel Mobile Pavilion is an example of how reflective materials can be used on the exterior of a demountable building to reflect the surrounding environment and, therefore, can fit into many different locations.

2.4.2.5 The Harley-Davidson[253] 'Machine Tent'

FIGURE 2.108. Inside the 'Machine Tent'[254]

The *Machine Tent*, (Figure 2.108.) was designed by FTL Design Engineering Studio, a studio with rich experience in the design of lightweight and tensile structures. This project was part of a larger travelling exhibition developed to celebrate the 100th Anniversary of the Harley Davidson Motor Company in 2002. The project was set up concurrently in five locations in the US, as well as in Tokyo, Sydney, Cologne, Mexico City, Vancouver and Barcelona. At each location the exhibition tent comprised a custom designed tensile structure. Creating a travelling structure for installation at locations all

[252] Zaha Hadid Architects, "Mobile Art Chanel Contemporary Art Container," http://www.zaha-hadid.com/architecture/chanel-art-pavilion/.
[253] Harley-Davidson is an American motorcycle manufacturer. It was founded in Milwaukee, Wisconsin during the first decade of the 20th century.
[254] 2008 FTL Architecture & Engineering Associates PC, "Harley Davidson Motor Company," (2002).

over the world required the logistics of various building regulations and equipment and manpower availability in these regions to be studied. A further challenge was the extremely short and limited delivery time. The total time available for design, engineering and fabrication for this tent was less than 20 weeks. The resulting Machine Tent was circular in plan and 48.7 metres (160 feet) in diameter. It comprised of a central mast and six secondary masts, organised in a radial arrangement and capped with a trussed arch, thus giving the canopy its unique form. The structure was designed to be self-erecting to reduce the installation time and manpower required. This was achieved by using trussed compression members with internally mounted motors and winches that hoisted both themselves and other components. The fabric was divided into six identical sections enabling quick fabrication and installation. Time available for installation was limited to a maximum of 3 days.[255]

Machine Tent was a success, not only because the design could be delivered within an extremely tight schedule but because the exhibition travelled as an open road tour and was, therefore, consonant with the Harley Davidson brand and products. The 'on the road' impression by the tent created had combined well with the Harley culture.

2.5 Conclusion

From the evidence presented and arguments discussed above, the following concluding parts can be made:

(i) The evaluation of the functional performance of demountable buildings can be considered through four main areas: function, finance, timescale and aesthetics.

(ii) Most large-scale demountable buildings are deployed in a single location. Most medium-scale and small-scale demountable buildings are deployed in multiple locations.

(iii) Some small-scale projects can be transported whole, instead of having to be dismantled for the next construction.

(iv) The five major demountable building structural systems - module, flat pack,

[255] Ibid., 2011.

tensile, pneumatic, and combined system - give different building appearances. They all generally appear light in weight compared to static buildings.

(v) Glass, concrete, wood, metal and plastic are five major materials have all been used in demountable buildings. Apart from these, paper, cardboard, bamboo, natural fibre and many less common unusual materials can also be used in building construction.

(vi) The use of demountable buildings addresses the importance of public space. Without the availability of public space, many demountable building constructions would not be possible. This brings a new proposition of using demountable buildings as a method to explore urban growth (see Chapter 5).

The following table, which summarises the contents of this chapter, is used as a valuable reference in later chapters. These findings establish the fundamental knowledge about the design and operation of demountable buildings. This is essential for developing the evaluation indicators for the next research stage.

TABLE 2.8. Key Factors of Design and Operation in Demountable Buildings

KEY FACTORS OF DESIGN AND OPERATION IN DEMOUNATBLE BUILDINGS	**Function**	Spatial Comfort			Anthropometrics, ergonomics, disability and ability, circulation spaces, activities, furniture arrangements and storage considerations. The key question is how to use the limited space for end-users' maximum comfort?
		Usability			Usability shows how convenient it is for the clients to host activities inside the building and how easy it is for the building users to participate in these activities. Usability of a building can be measured by analysing the features of the building. The method of performing usability measurement relies on qualitative analyses which include interviews and surveys.
	Finance	The cost of the building proper: construction materials, building machinery and tools. The cost of the physical plant: hiring construction workers, design service, operation and transporting building elements or components. The cost for allocation including: renting the building site (indoors or out door), administrative services, allocating the waste building materials. Dismantling the building and transporting the components for future use. Costs reduction through re-use of the building components. Transportation cost reduction through using local available materials.			
	Timescale	A timescale and clear aims are normally established and agreed during the briefing process. Gantt Chart, Microsoft Excel and Network Analysis Software can be used to aid architects and project managers to schedule realistic tasks. The general project view needs to be broken down into manageable working tasks.			
	Aesthetics	Visual Appearance	Scale	Large	Often used for: temporary stadium and arena design, large concerts or large stores Often deployed after use and will not be constructed again as the same building.
				Medium	Often used for temporary exhibitions, community centres, schools, offices. They are most widely used. Often will be constructed again as the same building after deployment.
				Small	Often used for temporary residential spaces, mobile shops, portable clinics. Often are addressed as demountable structures rather than buildings.
			Structure	Module	Based on modules, or certain standard sizes and multiples of those sizes, often associated with industrialised buildings and prefabrication. Often constructed or produced off-site. Common modular system, demountable buildings, include: shipping containers temporary building and prefabricated buildings.
				Flat Pack	Normally are delivered in parts and constructed on site. The components are often pre-made in factories and they are relatively easily constructed. Common flat pack demountable structures include: tents, yurts, marquee and domes.
				Tensile	Structure formed mostly of components acting in tension rather than compression. Commonly used tensile structures include: tents, marquees.
				Pneumatic	Inflatable structures that are supported by air pressure and are rapidly demountable. Commonly used pneumatic building components and structures include: inflatable roofs and tents.
				Combined System	They contain more than one structural system.
			Material	Glass	A hard, brittle, usually transparent material which is used to provide structure, enclosure, and luminance. Sometimes used for decorating building or used within a perforated façade as windows. Because of its normally high cost per volume, glass is often replaced by transparent plastic.
				Concrete	Strong in compression, and when enhanced by steel reinforcement can also have great tensile strength. Concrete can take any shape or form through casting, and can have a variety of surface textures, finishes, and colours. Concrete is not usually used as a material for demountable building design, but it can be an important foundation material for the demountable buildings. Concrete buildings which are demountable can use all the advantages of 100% off-site prefabrication
				Wood	Natural, organic, lightweight, strong, readily accessible, and simple to work with in construction. Its wide variety of colours, textures, grain patterns, and fragrances give designers a versatile and adaptable expressive tool for construction.
				Metal	Elements made by the refinement of minerals, each with unique qualities derived from their constituents and the process used to produce them. Metals are entropic-they can be re-covered, re-formed, or mixed together to form totally new metal types.
				Plastic	Lightweight, resilient, generally resistant to corrosion and moisture, and can be moulded and formed into complex shapes.
				Paper	Not common building material, but has a great potential for building construction.
				Others	There are many other materials can be used, include a variety of man-made or natural materials, such as mirror, bamboo and snow.
			Colour	The factors affecting users' recognition of the colour of a building, include the surroundings of this building, material, and the lighting and weather conditions under which it is seen. Apart from physical conditions, users' understanding of colour is also related to culture.	
			Illumination	Due to the variety of the materials which can be applied to demountable buildings, the texture of the selected material can create many different illumination effects.	
		Acceptability to Users	Mainly due to the assessment of the 'building friendliness', which means how well the design of the building is accepted by people psychologically. Acceptability by the users leads to the satisfaction of users.		
		Appropriateness at the Building Sites	The arrangement and positioning of a demountable building not only depends on the availability of the construction space, but also depends on the position of the surrounding existing buildings		

3

Review and Synthesis of Analysis and Evaluation Methods

3.1 Introduction

At the time of writing, there are few documented or practical evaluation/analysis methods specifically designed for demountable buildings. During this research process designers of demountable buildings, started a tendency to evaluate projects through empirical experience gained from other demountable or static building projects. In the past, a variety of standards, principles, software and multi-dimensional methods, originally designed for other purposes, have been used, in part, for demountable buildings, such as, ISO (International Organization for Standardization) Standards, including ISO 14000, written initially for environmental protection systems. Guiding principles for shelters after disasters, such as Habitat (*United Nations Centre for Human Settlements Guidelines for the Evaluation of Post Disaster Programmes*), have been taken as a framework for evaluating rehabilitation interventions in human settlements. Assessment systems such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method) and CASBEE (Comprehensive Assessment System for Built Environment Efficiency) have been used for providing practical and measurable green building frameworks. Software such as ASPIRE (A Sustainability Poverty and Infrastructure Routine for Evaluation), IES (Integrated Environmental Solutions) and DesignBuilder have also been implemented as evaluation tools. In addition, more specific methods and guidelines, such as CASBEE for Temporary Construction Criteria, *Temporary Structures in Historic Places (Guidance for Local Planning Authorities, Site Owners and Event Organisers)* by English Heritage and *Temporary Building*

Design Guide by Aberdeen City Council, have been modified for use in demountable building designs. These evaluation methods belong to various different technical fields and scientific disciplines, such as economics, different branches of engineering, structural technology, architecture and town planning. The previous chapter, concluded that evaluation means establishing a set of criteria as an evaluation option, which enables project operators to begin to address functional performance from a public perspective and reflect on the scope of their projects. This chapter introduces the comparative evaluation and analysis methods that are currently in use, and investigates the similarities and differences between them. It begins by discussing the role of evaluation in the demountable building design process, followed by outlining the principles and process of evaluation. The chapter concludes by introducing, in detail, the methods, which are divided into three groups: *Guidelines Developed by City Councils and Cultural Sectors*; *Methods in Humanitarian Responses* and *Methods in Environmental Assessment*.

3.2 The Role of Evaluation in the Demountable Building Design Process

The design process of demountable buildings is similar to that of conventional buildings in terms of providing the required function for clients and users. However, there are some key factors with this architecture type that distinguishes demountable buildings from traditional buildings:

- A demountable building is usually required to be completed and ready to use within a short time. Depending on the level of urgency, the request could be for the design to be as straightforward as possible to allow for fast construction. In some situations, such as for disaster relief projects, many demountable structures have already been stored and made ready for transportation to the affected areas.

- Most demountable buildings and structures require no foundations, removable foundations or small foundations because they are relatively light weight. However, heavier material such as concrete is commonly used for container structures, and steel, timber and wood are also often used for small-scale structures.

- In addition to meeting fundamental requirements, an important goal is to design for easy assembly and rapid disassembly in mind. This often requires the building components to be detached from each other with flexible joints.

- The designers of demountable buildings and functional structures are often not architects. Many product designers, artists and engineers have particular interests in the design of this type of architecture.

Yehuda E. Kalay states in his book, *Architecture New Media* (2004), that design is comprised of three major activities, performed iteratively: designing a set of goals that the proposed solution ought to achieve; developing a solution that, in the opinion of the designer, will achieve the goals; and predicting and evaluating the performances of the proposed solutions to verify that they are consistent with each other and will achieve the goals.[1] This summary is broad, and it is difficult to define the objectives of the design process without searching for solutions that achieve them.

Kalay developed a diagram (Figure 3.1.) to explain the role of evaluation in a design process. It shows that evaluation plays a central role, and is responsible for the iterative structure of the process by combining the design goals and solutions.[2] This proves the importance of evaluation, as Kalay writes: "The evaluation guides the generative process toward achieving the stated objectives, uncovers opportunities to be explored, and indicates tradeoffs that must be made in order to improve the overall quality of the solution."[3] Evaluation, therefore, is important for defining and clarifying the design process goals, as well as for guiding the development of the solution. Kalay suggests that evaluation relies upon the designer's ability to predict the environmental, psychological, social, economic and other effects that will ensue from realising the specified solution, in order to derive operational conclusions from that evaluation.[4]

[1] Kalay, *Architecture's New Media : Principles, Theories, and Methods of Computer-Aided Design*: 302.
[2] Ibid.
[3] Ibid.
[4] Ibid.

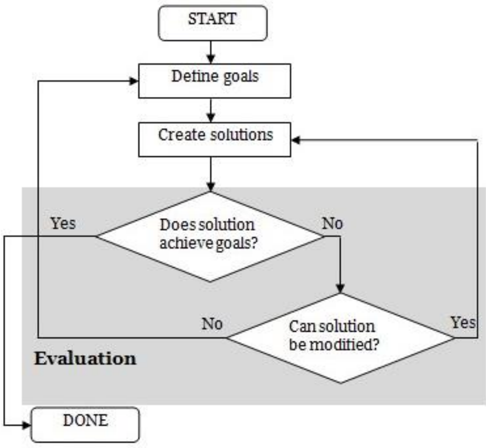

FIGURE 3. 1. The iterative structure of the design[5]

It could be argued that evaluation can be seen as a part of the design process, and each design criterion may need knowledge of a specific area, for example, the evaluation of the function requires different criteria to the evaluation of the project finance. Methods that recognise the complexity of evaluation, and its dependency on other aspects of the design process, have been developed, such as ASPIRE (A Sustainability Poverty and Infrastructure Routine for Evaluation), a computer programme is based on the SPeAR® software platform by Arup and EAP. It carries out the assessment with respect to four sectors: institutions (structures, skills, policies, reporting); environment (air, land, water, biodiversity, energy, materials); economics (equity, livelihoods, macro, viability) and society (population, culture, stakeholders, services, health, vulnerability). In addition to ASPIRE, other methods have been developed for the evaluation of architectural projects. To understand the motivations behind these methods and how they can be integrated into a comprehensive evaluation criteria framework, it is necessary first to better understand the principles underlying evaluation and how it is used in the design process.

[5] ———, "Architecture's New Media: Principles, Theories, and Methods of Computer-Aided Design," ed. The iterative structure of the design process and evaluation's central role in it (Cambridge, Mass: MIT Press, 2004), 302.

3.3 Functional Performance Evaluation Principles

Functional performance evaluation principles are discussed with consideration to four questions:

(i) What is the evaluation going to be used for?

(ii) Who conducts the evaluation?

(iii) How can the results of the individual evaluation criteria be integrated into a composite measure of criteria?

(iv) What happens after the evaluation?

1) What is the evaluation going to be used for?

The evaluation results can be used by clients, designers or other stakeholders. For the benefit of the clients, a robust evaluation can help them to assess whether all the design objectives have been achieved and assist them in planning for the future of the building. For example, following the first exhibition of a demountable building, it can help them to decide whether to reuse the entire building or partly recycle the building components. With respect to the designers' interests, a good evaluation can help them assess the success of their design strategies. It is useful for the designers to obtain an overview of their work in order to gain understanding from the users' feedback.

2) Who conducts the evaluation?

Chapter 2 showed that the functional performance of small-scale public demountable buildings can be examined from the perspectives of function, finance, timescale and aesthetics. The four areas may be of differing importance to differing stakeholders. The client might be particularly interested in assessing function, finance and timescale during evaluation because they normally provide the project funding and communicate with the end-users directly. The designer might be particularly interested in assessing function and aesthetics during evaluation because they design the building and are keen on the quality and appearance of the project. They are often interested in finance as this is usually a specific requirement of their client. An external evaluator, as a consultant, might be interested in all aspects. Depending on the priority of each evaluation criterion, the evaluator could be the client,[6] designer or consultant/external evaluator. Within a project development team, each party may have particular expertise in evaluating a specific area. For example, in some cases, often where the project is small-scale and the designer has full access to the information, the designer can be a better option for conducting a valid evaluation than an external consultant.

3) How can the individual evaluation criteria be integrated into a composite measure of criteria?

The third question pertains to integrating the various evaluation criteria measures into one composite whole, which will qualify as an overall measure of the evaluation value. This can be achieved by weighting the importance of each performance characteristic relative to others. It can be argued that the overall value of an evaluation is subjective, because what is important to the designer may be less so to the client.

In order to answer the above question, Kalay divides evaluation criteria into two parts: "evaluating quantifiable qualities"[7]; and "evaluating non-quantifiable qualities".[8] The quantifiable qualities include the structural performance of a building, its overall costs, the level of thermal comfort it provides to its users and the level of acoustic insulation it offers. Each of these performance characteristics benefits from an extensive body of research and a host of computational tools that have been developed over the years for its evaluation.[9]

The non-quantifiable qualities are the important building characteristics that are not amenable to quantitative evaluation, such as architectural aesthetics and how well it meets its visitors' functional needs in terms of size, proportion and usability. The *good* or *bad* performance of non-quantifiable qualities is comparable and changeable, depending on the specific built environment and amongst other factors, the visitors' ages, cultural backgrounds.[10]

[6] In this thesis, "client" does not refer to the project owner because, in many small-scale demountable buildings, the project owners are the designers themselves. For example, in the two case studies within this research, the designers of both Exxopolis (an Architects of Air project) and Kreod own the exhibition structures, and their clients include promoters, event organisers and project sponsors.
[7] Kalay, *Architecture's New Media : Principles, Theories, and Methods of Computer-Aided Design*: 357.
[8] Ibid., 375.
[9] Ibid., 357-74.
[10] Ibid., 375-90.

When all the evaluation criteria (function, finance, timescale and aesthetics) cannot be equally satisfied during assessment, the evaluator may establish the relative importance of competing or even conflicting criteria. This prioritisation will then allow the evaluator to determine the overall merit of the project and compare it to other evaluators' results.

4) What happens after the evaluation?

As well as establishing the relative importance of the evaluation criteria, another important principle of evaluation is analysing the building through time. Francis Duffy[11] states that "the unit of analysis for us isn't the building; it's the use of the building through time. Time is the essence of the real design problem."[12] Stewart Brand adapted Duffy's theory and developed it into the Shearing Layers of Change.

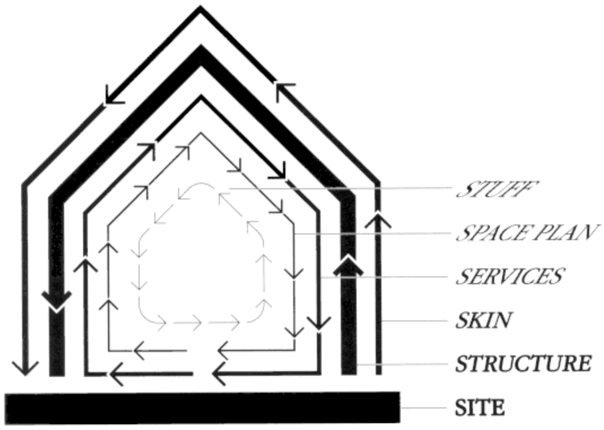

FIGURE 3. 2. The Shearing Layers of Change[13]

The Shearing Layers of Change[14] shows that *stuff* (furniture or flexible walls inside the building) is the easiest component to change, followed by *space plan*, *services*, *skin* (façade), *structure* and *site*. *Stuff* basically includes everything inside a building, such as furniture, decorations and flexible walls that can be moved around daily or monthly. *Space plan* is the interior layout, which includes ceilings, walls, floors and doors, can be flexible according to the building structure. *Services* include electrical

[11] Francis Duffy was born in 1940. He is a British architect and the founder of DEGW, the international architectural and design practice. He was president of the Royal Institute of British Architects (RIBA) from 1993–95 and was appointed a Commander of the Order of the British Empire in the New Year Honours 1997.
[12] Stewart Brand, *How Buildings Learn : What Happens after They're Built* (New York: Penguin Books, 1995), 13.
[13] Frank Duffy, " The Shearing Layers of Change," (1990).
[14] Shearing Layers is a concept created by architect Frank Duffy and later adapted and elaborated on by Steward Brand, referring to buildings as being composed of several layers of change – *site*, *structure*, *skin*, *services*, *space plan* and *stuff*.

wiring, plumbing systems, sprinkler systems, heating, ventilation, air conditioning and elevators, and they are examined, and normally need to be replaced, on a regular basis. *Skin* is the façade of a building that is regularly painted and repaired. The increasing focus on energy efficiency has led to more flexible exterior surfaces that can be made from many different materials. *Site* is the geographical setting, or location of a building, which does not change unless natural disasters happen or large-scale site development occurs.

The Shearing Layers of Change is also applicable to small-scale public demountable buildings. *Site* refers to the geographical setting, with the difference from static buildings being that small-scale demountable buildings/structures can sometimes be constructed inside a building if necessary. *Structure* is the foundation of the building/structure, but many demountable buildings have a flexible structural system, such as module, flat pack, tensile, pneumatic and combined systems. The *skin* (exterior surface) of a demountable building is usually determined by structure, materials, colour and lighting systems. The *services* include, as above, communications wiring, electrical wiring, heating, ventilation and air conditioning. *Space plan,* also as above, refers to the interior layout and *Stuff,* once again, includes chairs, desks/tables, any other furniture for exhibitions and small building facilities such as fans, televisions and projectors.

An analysis of the use of demountable buildings can be achieved by examining a series of layers (site, structure, skin, services, space plan and stuff) that change throughout the lifespan of the building. After the first round of evaluation, some buildings are completely reconstructed following redeployment, some are partly re-used and some are entirely recycled. Depending on the specific function offered by a demountable building, the evaluation criteria and suitable assessment methods may also change.

3.4 The Evaluation Process

This section briefly discusses the general process of evaluation in theory. The most widely used evaluation method is a traditional “pre then post” test, where participants are asked a series of questions both at the beginning (pre-test) and then again at the programme’s completion (post-test). This evaluation method measures changes in the development of a demountable building design. Normally, terms such as *pre-occupancy evaluation* and *post-occupancy evaluation* are used by researchers or consultants when they are evaluating residential building projects. Both pre-occupancy and post-occupancy evaluation can be conducted through questionnaires, in-depth semi-structured or face-to face interviews, and computer software techniques to examine users' perspectives on building performances in terms of function and energy cost consumption. The focus here is on post-occupancy evaluation because the functional performance of a demountable building is best revealed during this process after it opens to the public.

Pre-Occupancy Evaluation

Pre-occupancy evaluation can be understood as an assessment process carried out at the early stages of the design of demountable buildings. At this stage, designers often use software and models to estimate the project costs and construction time. Many projects can be delayed for various reasons, such as costs, the availability of materials, construction machinery or the weather. In some circumstances, conducting a pre-occupancy evaluation is essential for the clients to obtain permission for construction on site. For example, one of the research case studies, the Kreod project, was evaluated by the designer before the construction started on site in order to obtain permission from Greenwich Council. In its *Design and Access Statement*, the designer introduces and analyses the project from eleven perspectives: site location, social context, planning policy context, design, use, scale, layout, landscaping, appearance, access statement (accessibility, implementation, building approach and access, public circulation) and public toilets. Specifically, it claims that "no trees are to be felled in order to facilitate the proposed development".[15] Special consideration was given towards the accessibility of the structure:

> It is the intent of the design for the Kreod to facilitate an inclusive, accessible environment for all users of the pavilion. Where appropriate we have designed the scheme in accordance with Part M of the Approved Documents of the Building Regulations and BS 8300: 2009. This will not only provide an environment that addresses the needs of those with disabilities but also provide benefits to others (e.g. older people, families with small children) by the improved accessibility. Disabled users will not be treated in any manner less favourably than those who are able bodied for a reason due to their disability.[16]

[15] Chunqing Li, "Design & Access Statement," http://onlineplanning.greenwich.gov.uk/acolnet/documents/51488_4.pdf (assessed 11 November 2011).
[16] Ibid.

Pre-occupancy evaluation is also important in aiding the management of project schedules and to ensure deadlines can be met.

Monitoring

Once a decision is made to build, monitoring is essential. The *Guidelines for the Evaluation of Post Disaster Programmes* state that monitoring can be understood as a continuous process throughout the project cycle that assists managers in assessing early signs of positive impacts or potential problems in the project. Evaluation, although it is closely linked with monitoring, is more structured, and is carried out at specific intervals during the project cycle. Monitoring is usually based on judgement, whereas evaluation is more selective and determines specific criteria such as relevance, success and performance of the project.[17]

As such, monitoring is the systematic and continuous collecting and analysing of information about the progress of a project or programme over time. It is useful for identifying strengths and weaknesses in a project or programme and for providing those responsible for the work with sufficient information to make correct and timely decisions to improve quality. Information about the work, the impact it is having and the external environment needs to be collected and analysed on a continued basis. The results can then be fed directly back into the planning process and any necessary changes can be made. Monitoring ensures that the work stays on course, by checking that activities are implemented, measuring progress towards objectives, identifying problems as they come up, identifying strengths and adapting to changing circumstances. Monitoring is the key to good planning, and the more effective the process, the easier it is to carry out the subsequent post-occupancy evaluation.

Post-Occupancy Evaluation

Preiser et al. define post-occupancy evaluation (POE) as:

> The process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time. POEs focus on building occupants and their needs, and thus they provide insights into the consequences of past design decisions and the

[17] The United Nations Centre for Human Settlements (UNCHS) Habitat and Unit, *Guidelines for the Evaluation of Post Disaster Programmes : A Resource Guide*: 14.

> resulting building performance. This knowledge forms a sound basis for creating better buildings in the future.[18]

POE can determine whether a project has achieved the original design intentions and expectations, and assesses the comprehensive effects after the project is put into operation. In addition, POE enables decision-makers to grasp the effects of project investment to improve the investment objectives and evaluation system. POE methods can help analyse human responses to existing buildings, and these methods assess the behaviour of people in settings such as schools, offices and exhibitions. Its purpose is to find correlations between a building and the behaviour of its inhabitants for the purpose of improving current situations or for developing knowledge that can guide the design of similar facilities.

One of the better known of such studies is William Whyte's video documentary of small urban places in New York City (1980), which led to the formulation of municipal design ordinances intended to improve the urban landscape. The 55-minute film is the result of a three-year research programme entitled *The Street Life Project*. The research group studied a cross-section of spaces, which included sixteen plazas, three small parks and a number of small spaces. The team used cameras and clocks marked the points in time to enable evaluation of the film.[19] Whyte states that evaluation is the critical point in the whole filming process, and that the essential thing to do is to "interrogate the film",[20] which means asking questions when running through it. Whyte suggests that running the film back and forth at a fast speed is a creative method of evaluation, because previously unnoticed things can be identified in this way.[21]

Shiem-Shin Then argues that POE can be used to deal broadly with the relationship between a building and its users from social and cultural perspective.[22] He also shows that POE has been accepted and supported by "tools and techniques that attempt to bridge the divide between the design, construction and building-in-use phases of the building life cycle, both in terms of communication during project brief

[18] Wolfgang F. E. Preiser, Harvey Z. Rabinowitz, and Edward T. White, *Post-occupancy Evaluation* (New York: Van Nostrand Reinhold, 1988), 3.
[19] William Hollingsworth Whyte, *The Social Life of Small Urban Spaces* (Washington, D.C.: Conservation Foundation, 1980), 16.
[20] Ibid., 109.
[21] Ibid.
[22] Danny Shiem-Shin Then "Post-occupancy Evaluation" In John Kelly et al., *Best Value in Construction* (Oxford; Malden, MA.: Blackwell Science, 2002), 275.

formulation and construction period, as well as feedback from the occupiers of the building in use".[23]

There are few existing evaluation methods that directly address the functional performance of demountable buildings during the design process itself. This is because relatively little is understood about how people react socially, psychologically and cognitively to their physical environment. Analysing human responses is complicated by the influence of cultural factors, which are themselves the result of education, social habits and beliefs. People of different cultural backgrounds may have varying opinions about the same building, and, therefore, it can be argued that evaluating the impact of buildings based on visitors' responses is one of the most difficult aspects of functional performance evaluation. As Kalay concludes: "it requires an understanding of human perceptive and cognitive processes and the ability to interpret and evaluate them within complex socio-demographic and cultural contexts".[24]

3.5 A Review of the Existing Analysis and Evaluation Methods

According to *Temporary Demountable Structures: Guidance on Procurement, Design and Use* (2007), the principle responsibilities in demountable building design and construction are shared by three parties: the client, who is responsible for the safety of the users of the demountable building/structure; the local authority, who is responsible for statutory public safety controls in some circumstances; and the contractor, who is responsible for the design, erection and dismantling of a demountable structure, as well as for arranging independent design checks.[25]

It is important for all three stakeholders to be familiar with a comprehensive legal reference source throughout the construction and deployment processes. For example, *Construction Law Handbook* (2009), by Robert Frank Cushman et al. can be used as a reference to identify legislation relevant to demountable buildings, because it covers a wide range of the topics most commonly required for all types of buildings, and it is the most up-to-date edition containing reliable and practical

[23] Danny Shiem-Shin Then "Post-occupancy Evaluation" In ibid., 277.
[24] Kalay, *Architecture's New Media : Principles, Theories, and Methods of Computer-Aided Design*: 376.
[25] Institution of Structural Engineers, *Temporary Demountable Structures : Guidance on Procurement, Design and Use*: 6.

advice from professionals. However, it must be noted that building regulations vary between different countries, and design changes can be requested by the local authority or construction site owner.

3.5.1 Guidelines Developed by City Councils and Cultural Sectors

Demountable buildings and functional structures are frequently seen in public spaces such as plazas, parks, gardens, courtyards and lawns, as well as inside large-scale malls. Permission is normally granted by city councils or cultural sectors in advance of installation. It is common for individual countries, cities and districts to have different policies or guidance based on the local social and natural environment.

3.5.1.1 Temporary Buildings Design Guide by Aberdeen City Council

The *Temporary Building Design Guide* (2008) was developed by the Enterprise, Planning and Infrastructure department of Aberdeen City Council, UK in 2008. The purpose of the guidelines was to provide guidance to companies or organisations needing to apply to Aberdeen City Council for planning and construction permission for portable buildings, installations or demountable building constructions on commercial or industrial sites.[26]

In the guidelines, portable buildings have been defined as buildings that have integral jack-up legs for support, and are designed to be upon the disconnection of any main services, transported as a unit from site to site by cranes.[27] In order to be granted permission, the portable building unit must be sited to the rear of existing buildings, avoid the loss of existing car parking spaces and not be sited on landscaped amenity areas, especially those with established tree and shrub planting. The *Guide* states that permission can be normally granted for a year, and up to a maximum of two and a half years. It is only in exceptional circumstances that permission would not be renewed on the expiry of this first period.[28]

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[26] Aberdeen City Council, "Temporary Building Design Guide, Supplementary Planning Guidance,"(2008), http://www.aberdeencity.gov.uk/web/files/LocalPlan/temporary_buildings.pdf (assessed 16 July 2012).
[27] Ibid.
[28] Ibid.

In all other instances, however and providing that the portable building has been maintained in a satisfactory condition and without significant change in the planning circumstances, there should not be any difficulty in obtaining permission for retention as long as the two-and-a-half-year limit is not exceeded.[29]

Demountable buildings have been defined in the guidelines as “those units that are erected on site using prefabricated sections to form a building which is fixed into prepared foundations, and is therefore of a more permanent nature”. The demountable buildings must be sited with the same siting criteria as for portable buildings. In recognition of their greater durability, planning permission will generally be granted for an initial period of five years, and thereafter, units may be considered for additional, shorter periods, providing that the buildings have been maintained in a satisfactory condition and the application can present a justifiable case for the continued use of a temporary building rather than the erection of a permanent replacement. Permission for the retention of such units beyond ten years will only be granted in exceptional circumstances which have been very carefully considered on their own merit. In all instances, the Council’s car parking standards will apply.

These guidelines often limited detail on explanations and further recommendations. However, a simple guideline can be used for the clients of the demountable building projects to transfer information from evaluators, with more detailed description for criterion further explained in separate documents.

Many types of demountable structure have been regularly constructed in Liverpool ONE, including domes, tents and other moveable structures such as funfairs and small containers. In an email from the Building Fabric Manager, Christopher Lee, at Liverpool ONE, in response to enquiries regarding the site management, he stated that:

> Event space in front of John Lewis has temporary structures provided by third party contractors who hire this space as a commercial venture for Liverpool ONE. The events on the park are normally in a direct contract by Liverpool ONE as part of the enlivenment of the park and has varied year on year. Starting the 23 October will be the build for Xmas 2012 which will include 5 temporary structures on the park and 1 outside John Lewis. The only structure that Liverpool ONE manages is the dome that will be outside John Lewis this Christmas.[30]

[29] Ibid.
[30] Christopher Lee, 2012.

FIGURE 3. 3. - 3. 5. A Christmas dome at Liverpool ONE; A temporary commercial structure; A large tent in front of John Lewis, the department store

These small-scale functional structures have benefited from the "large lump development"[31] and are used to join up the building blocks to provide a coherent shopping experience for the visitors. Although no regulations or guidelines were available from Liverpool ONE, it was clear that the management team tries to provide maximum flexibility for clients and contractors, thereby encouraging the use of small sites between buildings.

3.5.1.2 Temporary Structures in Historic Places – Guidance for Local Planning Authorities, Site Owners and Event Organisers by English Heritage

There has been an increasing number of proposals for temporary structures in historic places being referred to English Heritage[32] for comment. They include tents, marquees, temporary seats and stages, large television screens, events ticket offices, toilets and containers. English Heritage prepared guidance over the summer of 2009, aiming to provide guidelines for conservation officers in local planning authorities, owners of heritage sites, event promoters and expert advisers. The guidance was developed in consultation with representatives of stakeholder organisations and acknowledges the benefits of temporary structures, as well as the potential problems with regards to the sustainability of heritage sites. The guidance explains how the various statutory planning controls may apply and suggests how to minimise visual intrusion and prevent physical damage through careful planning

[31] Carmona et al., *Public Places Urban Spaces : The Dimensions of Urban Design*: 264.
[32] English Heritage is officially known as the Historic Buildings and Monuments Commission for England – an executive non-departmental public body sponsored by the Department for Culture, Media and Sports. English Heritage is the statutory adviser to the English Government on the historic environment, and has the responsibility to protect both the natural environment and the historic built environment of England.

and management of temporary structures and events.[33]

This guidance first addresses the importance of the local council authority. All local councils have a duty of care to all historic areas under their jurisdiction. This is done through the application of development and planning policies, whilst abiding by existing legislation for the concerned areas. Their responsibilities also extend to the issuing of licensing permits, traffic changes for buildings, and the effect on the environment caused by the temporary structures themselves. Local councils control their planning debarments with the help of experts, either internal or external, to obtain the best advice. Planning permissions are administered by the relevant local councils and include consent for advertisements, buildings and tree and hedge conservation. Scheduled monument consent is slightly different, and advice is given by English Heritage to the secretary of the Department for Culture, Media and Sports (DCMS), who makes the decisions as to whether consent is given for the project to go ahead. Planning applications have to take into account the effects of noise, ecological damage and, lastly, the historic environment.[34]

The *English Heritage Charter* lists the services provided through its advice for pre-application planning, development, non-statutory advice and listed building consent. It provides a non-consultancy service for planning authorities for regarding important applications about the historic environment and archaeology in Greater London. The guidelines by which they work are set out in the *Planning Policy Statement (PPS) 5: Planning for the Historic Environment: Historic Environment Planning Practice Guide* (2010), which covers English Heritage and local council planning authorities.

Instruction guidelines have been produced in the form of an *Historic Environment Planning Practice Guide*, which allows planning authorities to see how proposals accord with both PPS and the Practice Guide, and whether they are beneficial or harmful to English Heritage's Conservation Principles (2008). It enables them to make consistent outcome, so that there is a clear understanding of the effects of any proposed change.

When evaluating proposals in the planning system, the aspects considered and examined consist of location, physical impact, visual impact, setting, design,

[33] English Heritage, "Temporary Structures in Historic Places - Guidance for Local Planning Authorities, Site Owners and Event Organisers,"(2010), http://www.english-heritage.org.uk/publications/guidance-on-temporary-structures-for-events/ (assessed 30 July 2012).
[34] Will Holborow, July 24 2012.

duration and season, public access, financial benefits and enabling development.[35] English Heritage recommends that local planning authorities examine all these factors when they consider whether to grant planning permission for temporary structures in historic places. Each proposed case needs to be considered on its merits.[36]

Location – if the site is of national importance, English Heritage can ask the proposer why they have chosen that particular part of the site and to justify their decision. This way, English Heritage may be able to see which location carries the lesser impact or whether another part of the site would be more appropriate. However, economics and access to services will have to be taken into consideration in making this decision.[37]

Physical impact – applications for temporary structures may involve the removal of trees, widening of roads or tracks, or ground works to accommodate the event. Local authorities must give permission before these works are carried out. The local planning authority should look at exactly what the impact of works are, whether these impacts can be reversed and at what cost, and the effect on any listed buildings and scheduled monuments. Risk-assessments for accidents that may cause damage to them or to protected trees will also be concluded.[38]

Visual impact – When choosing a location, the visual impact on heritage assets and their setting should be considered, and any adverse impact on key views should be minimised, both within the site and beyond.[39] The duration of the structure and the season of the event are important factors. The unsightly impact of areas used for storage, deliveries and generators can be reduced with good layout and screening. Impact can be also minimised by the use of existing features, e.g. the cover of trees in certain seasons, the actual duration of events and walls. The visual impact of any advertising will also need to be taken into account. This should be considered on site and beyond, so as not to overly impair views.[40]

Setting – Setting is defined in PPS 5 as:

> The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve.

[35] English Heritage, "Temporary Structures in Historic Places - Guidance for Local Planning Authorities, Site Owners and Event Organisers". 14-18.
[36] Ibid., 14.
[37] Ibid.
[38] Ibid.
[39] Ibid.
[40] Ibid.

> Elements of a setting may make a positive or negative contribution to the significance of an asset, may affect the ability to appreciate that significance or may be neutral.[41]

English Heritage states that applications for developments affecting the setting of a heritage asset need to be considered in accordance with Policy HE.10 of PPS 5. The factors that should be considered in the setting include the visual impact of the temporary structure, the noise impact and the duration of the proposed temporary structure.[42]

Design – the design of the temporary structure at the heritage site may affect views of the heritage assets. Sometimes, English Heritage suggests that the shape, material or even colours of the structures should be modified in order to suit their surrounding environment. Consequently, a pre-designed temporary structure is a better choice than a ready-to-use tent or marquee.[43]

Duration and season – English Heritage states that both the use time (duration) and the season of use of the temporary structure are important factors in assessing its impact because, for example, the impact of a marquee used for one week is much less than the same marquee used for a year. Depending on the season, the natural environment can influence the temporary structure, for example, a tree in leaf can be useful for screening the structures.[44]

Public access – English Heritage believes that temporary structures constructed at the heritage site can be beneficial in most cases because they attract visitors to a site. "Visitors" refers to the general public, and includes people with disabilities. The effects of temporary structures, in terms of encouraging visitors to enjoy the heritage, should also be considered.[45]

Financial benefits – English Heritages suggests that the proceeds from a revenue-generating event will often help to offset the operating costs of a heritage asset, including the costs of maintenance and repair.[46]

Enabling development – Planning Policy Statement 5 defines *enabling development* as "Development that would be unacceptable in planning terms but for

[41] Communities Great Britain. Dept. for and Government Local, *Planning Policy Statement 5 : Planning for the Historic Environment* (London: TSO (The Stationary Office), 2010), 14.
[42] English Heritage, "Temporary Structures in Historic Places - Guidance for Local Planning Authorities, Site Owners and Event Organisers". 16.
[43] Ibid.
[44] Ibid.
[45] Ibid.
[46] Ibid., 17.

the fact that it would bring public benefits sufficient to justify it being carried out, and which could not otherwise be achieved".[47] English Heritage states that this concept is, however, rarely applicable to temporary structures because it is designed to apply to permanent development.[48] If such approval is given to temporary structures, provision[49] should be made for the proceeds derived from the development to be spent on the heritage asset.[50]

In an email to the author on July 24 2012, Will Holborow[51] suggests that the guidance can be used as an evaluation tool for promoters to examine their project before obtaining the necessary permission. If permission is needed, this would be from the local authority, and English Heritage would only be involved in certain types of cases as set out in their *Charter for Planning and Development Advisory Services*.[52] Holborow further clarifies that promoters do not need the permission of English Heritage before they start work, unless this is a specific condition attached to a planning permission, listed building consent or scheduled monument consent. In most cases, it is for local planning authorities to decide if planning permission is required and, if so, to weigh up the benefits and detriments of a temporary structure. They may need to consult English Heritage in some cases, as mentioned above. There is no certification process involved in this, but conditions can be attached to permission.

3.5.2 Assessment Methods in Humanitarian Response

Shelter and reconstruction projects varying environmental considerations, for example, the destruction of infrastructures during earthquakes makes access difficult and, therefore, shelters need to be able to be transported by several means. Building collapse and suffer structural damage makes buildings uninhabitable and as a result, many survivors are left homeless and needing shelter immediately after the earthquake. Generally, different building typologies are affected, therefore, there is not only a need to provide shelters to use as dwellings but also as provisional

[47] Great Britain. Dept. for and Local, *Planning Policy Statement 5 : Planning for the Historic Environment*.
[48] English Heritage, "Temporary Structures in Historic Places - Guidance for Local Planning Authorities, Site Owners and Event Organisers". 18.
[49] These provisions can be achieved through an agreement entered into under Section 106 of the Town and Country Planning Act 1990.
[50] English Heritage, "Temporary Structures in Historic Places - Guidance for Local Planning Authorities, Site Owners and Event Organisers". 18.
[51] Will Holborow is the Head of GHEU (Government Historic Estates Unit) of English Heritage. He can be reached via direct line (0044)02079733804.
[52] Holborow.

hospitals, morgues, community kitchens and schools. Furthermore, large amounts of rubble need to be cleared before shelter assembly operations start, and aftershocks may disrupt this process and cause further damage.

Demountable buildings have been widely used to provide post-earthquake shelter solutions. These solutions are preferred by governments and humanitarian agencies to satisfy the urgent requirements of relief aid, due to their immediate availability, ease of transportation, storage and assembly. From a functional perspective, post-earthquake shelter solutions can be divided into two main types: those used as emergency solutions; and those for temporary use. Emergency solutions are applied straight after the event and often comprise lightweight fabric or canvas tents because they can be made more quickly and transported easily. The immediate aftershocks of earthquakes reduce in severity and frequency as time passes but the requirements for the living will grow, especially for disabled and impaired survivors. This leads to the second stage, in which transitional temporary shelters need to be provided before the re-building of permanent dwellings. During this process, professionally designed, pre-fabricated temporary houses that can be manufactured in advance for disaster mitigation can be used.

Many disaster relief standards have been used by agencies as guidance to help with post-disaster management work. After a disaster and before reconstruction begins, strategic environmental-impact assessments should be integrated into the decision-making process. Assessments provide the baseline necessary to judge resource stability, determine natural hazard risks and predict the immediate and gradual consequences of proposed activities.[53] At a minimum, rapid assessments can be applied, and although some agencies are standardising the use of assessments, many more either do not use them at all or manipulate the results to meet their needs.

In this section, assessment methods in humanitarian response and cultural development situations will be introduced, including: *UNCHS (Habitat) Guidelines for the Evaluation of Post Disaster Programmes*, *EMMA – Emergency Market Mapping and Analysis*, *Tearfund Shelter and Reconstruction Standards*, post-evaluation of container temporary housing through quantitative survey and structured interviews, toolkits developed by Save the Children, *ASPIRE (A Sustainability Poverty and Infrastructure Routine for Evaluation)*, and monitoring and evaluation post-disaster recovery using high-resolution satellite

[53] Anita van Breda and Brittany Smith, "Green Recovery" In Marie Jeannine Aquilino, *Beyond shelter : architecture and human dignity* (New York, NY: Metropolis Books : Available through D.A.P./Distributed Art Publishers, 2010), 174.

imagery. Whilst the latter focuses on collecting quantitative data, post-evaluation of container temporary housing uses both quantitative surveys and qualitative-driven interviews, and the remaining methods provide qualitative data.

3.5.2.1 UNCHS (Habitat) Guidelines for the Evaluation of Post Disaster Programmes

Ideally, post-disaster shelters should meet the urgent, hence important, needs of those who occupy them. However, the meanings of "shelter" and "users' needs" can be understood differently according to the source. In the dictionary, shelter is defined as something that covers or affords physical protection. In disaster relief projects, shelter designs aim to consider the victims' rights and allow them to live in safety and dignity. According to the *Guidelines for the Evaluation of Post Disaster Programmes* provided by UNCHS, there are certain components of the design that have a major impact on the programme's success, including: responding to the local needs; understanding the situation dynamics; misallocation of resources; short-termism; dependency vs. capacity; accountability; and quality assessment. The Guidelines emphasise the importance of realising that evaluation is not the end of a project, and it should be considered as a part of the post-earthquake cycle.[54]

The UNCHS Guidelines for the Evaluation of Post Disaster Programmes resource guide was developed by the UNCHS Risk and Disaster Management Unit (RDMU).[55] It provides a resource tool for local authorities to successfully manage and implement post-disaster programmes in order to minimise the effects of future catastrophes.[56] In these guidelines, four criteria are considered: transparency, independence, consultation; and relevance.[57] *Transparency* in evaluation is important to ensure an open, participatory approach to evaluation that involves all the participating parties and increases the sense of ownership in the project. Transparency ensures that the evaluation is not perceived as a top-down judgement. *Independence* does not mean that the project evaluator must be from outside the project team, but states that when the evaluation is performed by the project staff, the issue of an independent perspective is a priority, because independence can

[54] The United Nations Centre for Human Settlements (UNCHS) Habitat and Unit, *Guidelines for the Evaluation of Post Disaster Programmes : A Resource Guide*: 20-21.
[55] The RDMU was established in collaboration with the United Nations Volunteers (UNV) to address the demands of disaster-prone communities by increasing UNCHS (Habitat)'s ability to support countries and communities in their disaster prevention, mitigation and rehabilitation interventions in human settlements.
[56] UN-HABITAT, http://www.unhabitat.org/categories.asp?catid=9 (assessed 30 July 2012).
[57] The United Nations Centre for Human Settlements (UNCHS) Habitat and Unit, *Guidelines for the Evaluation of Post Disaster Programmes : A Resource Guide*: 16.

create an objective evaluation that is central to its ultimate credibility. Successful evaluation is a participatory process, and must therefore, be held in *consultation* with project staff and local partners. Evaluation methods should be consultative, i.e. utilising the deductive/inductive and participatory approaches and the overarching question that an evaluation assesses should be the *relevance* of a project. The question of whether the project is addressing the needs of the affected communities requires the evaluator to review the project process with reference to the objectives at the beginning.

The format of an evaluation must be clear and accessible to all project staff and local project partners. It addresses six key questions:

1) Why is the evaluation being undertaken?
2) What is the evaluation expected to achieve?
3) How will the results be used and by whom?
4) Who will conduct the evaluation?
5) What type of evaluation is most suitable?
6) How will the follow-up be carried out?

There are five steps in the evaluation process: preparing an evaluation plan; developing indicators; structuring indicators; undertaking the evaluation; and learning from the evaluation. The evaluation plan includes: organisation, partner organisation, programme summary, indicators for evaluation and collection of data, funding sources for the evaluation, evaluation schedule, type of evaluation (evaluation agents, evaluation scope), evaluation methodology (data collection, literature review and interviews with project staff and affected populations. Once the planned project is prepared, it is important to determine the indicators. The Guidelines identify the indicators as road signs throughout the project cycle that help to demonstrate where the project is and in what direction it is going. Furthermore, they show how effectively the project is travelling and whether it is progressing in the right direction. The indicators are designed to measure the project process, and they should be specific, measurable, achievable, realistic and trackable.[58] In these guidelines, the main indicators are the policy, programme and operational level effectiveness, efficiency, and programme/project impact.

[58] Ibid., 17-51.

Structuring indicators or establishing objectives, is a process of defining the exact criteria for each indicator, when undertaking the evaluation, the main methodologies are data collection (observation, discussion and interviews), attributing impact (measuring the impacts through both quantitative and qualitative data collection) and reporting the evaluation results. The final step is to learn from the evaluation, which includes following up the evaluation results, monitoring the follow-up and preparing a post-evaluation action plan to ensure that the evaluation process continues through the evaluation cycle.

Two lessons can be learnt from the Guidelines: that evaluation can be seen as a part of the project cycle and that, in some circumstances, an internal evaluator can be a better choice than an external evaluator. The Guidelines emphasise that evaluation is not to be separated from the design process. It is not always necessary for the evaluator to be someone or a group of professionals from outside the project. As such, it can be better for the project staff to act as evaluators because they have a comprehensive understanding of the process and they have the full correspondence details to ensure access to information.

3.5.2.2 EMMA – Emergency Market Mapping and Analysis (Toolkit)

The EMMA toolkit is a set of criteria that has been developed by the Emergency Food Security and Livelihoods team at Oxfam, UK in 2006 as guidance to assist humanitarian staff in emergency situations to better understand and accommodate the market systems of the affected areas. The key use of EMMA is to assist the establishment of humanitarian practices in diverse contexts by providing accessible guidance to staff who do not have expertise, experience or knowledge in market analysis. Mike Albu[59] clarifies that EMMA was designed to be used when the background information is limited; when the time and capacity to analyse existing markets are limited; when expert market-analysis capabilities are not available; once absolute priority survival needs are already being addressed; once displaced people have been temporarily or permanently settled; and once the producers, retailers and traders have had opportunity to assess their own situation and begin developing management strategies.[60] Albu also recommends using EMMA as a decision-making

[59] Mike Albu is a senior consultant of the Market & Livelihoods programme at Practical Action – a charity registered in the UK.
[60] Mike Albu, *The emergency market mapping and analysis toolkit* (Warwickshire: Practical Action Pub., 2010), 8.

tool in the first few weeks of an emergency situation, although it is also helpful for staff in the planning stage of disaster recovery projects.[61]

The EMMA process has three basic strands: *gap analysis*; *market analysis*; and *response analysis*.[62] *Gap analysis* helps users to understand the emergency situation and prioritise the needs and preferences of those most affected by the emergency. It also puts these needs or the gaps in their resources, into the context of their economic profile and livelihood strategies.[63] *Market analysis* helps users to understand each critical market system in terms of its constraints and capabilities in playing a role in the emergency response. It develops a map and profile of the pre-crisis baseline situation, and explores the impact of the emergency.[64] *Response analysis* explores different options and opportunities for humanitarian agencies and it looks at each option's respective feasibility, likely outcomes and benefits and risks, before recommending any action.[65]

The ten steps in the EMMA process, covering the general sequence of activities, are:

1) Essential preparation, including doing background research and in-country briefings, consultations on the agency mandates, terms of reference and practicalities, identification of target population and their priority needs.

2) Market selection of the most critical market systems for EMMA to study, using various specific criteria, and the identification of the key analytical questions that will guide the investigation of each system.

3) Preliminary analysis, which drafts initial provisional household profiles, seasonal calendars, and baseline and emergency-affected maps of the market system, and identifies key informants and useful leaders for field work.

4) Fieldwork preparation to agree and set the fieldwork agenda, devising the questionnaires, interview plans and information-recording formats needed for EMMA interviews and other fieldwork.

5) Field activities, where fieldwork activities are conducted, including interviews and gathering other information. This section requires guidance on interview methods and tips relating to different categories of information.

[61] Ibid.
[62] Ibid., 12.
[63] Ibid., 127-36.
[64] Ibid., 137-57.
[65] Ibid., 159-83.

6) Mapping the market to produce final versions of baselines and emergency market maps, as well as seasonal calendars and household profiles that describe the situation and inform the three “analytical” steps that follow.

7) Gap analysis, which uses household profiles, information and priority needs, shortfalls and access constraints in order to finally estimate the total gap that needs to be addressed.

8) Market analysis, which completes the market-analysis strand, using market maps and data to analyse availability, conduct and performance, and thus estimates the capacity of the market system to meet the gap.

9) Response analysis, which finishes the response-analysis strand, making reasoned recommendations (based on the market system logic, feasibility, timing and risks of different options), including cash, in-kind relief or other market support.

10) Communication of results which includes consultation with colleagues and communication of EMMA’s results to wider audiences (donors, agencies), using concise briefings and eye-catching map-based presentations and reports.[66]

EMMA can be used as step-by-step guidelines that are easy to understand and can be adapted to different disaster situations. It has been used in practice as a training course or guidelines in many countries, such as Indonesia (2010), Bangladesh (2010), Kenya (2010), Haiti (2010) and Liberia (2011), to address refugee crises and humanitarian issues. The author suggests that EMMA needs to be reviewed with up-to-date information in order to respond to complicated emergency contexts.

3.5.2.3 Tearfund Shelter and Reconstruction Standards

Tearfund is a Christian relief and development agency based in the UK, which works across the world to respond to disaster relief and recovery through church-based organisations. The process of providing guidelines requires the investigators to have close communications with the local authorities and actual building users. Social science skills, such as interviews, surveys and conversations, are particularly important in achieving their aims. The principles of Tearfund-supported Shelter and

[66] Ibid., 14.

Reconstruction projects are to reflect Tearfund's internal and external quality commitments; reflect adequate time for planning and implementation with a long-term commitment to participating communities; recognise the demands of such projects and ensure adequate funding and logistical support is available; be led by suitably qualified staff; build better and safer shelters; strengthen the capacity of survivors and support community-based recovery; give priority attention to the requirements of people with special needs and strengthen the role of local churches, local government and local institutions; and effectively prepare for future disaster.[67]

The principles were drafted by Ian Davis[68] who has been working in disaster management since the 1970s. In his early book *Shelter After Disaster* (1978), he lists six disaster charts based on the relief work and reconstruction activity that he had direct experience of as an observer or consultant. In each case, Davis lists a summary of major lessons learnt, such as, in the case of Skopje, Yugoslavia:

- The contingency organisation was highly effective
- The tents were not all used
- The evacuation policy was partially effective (all returned within 3–4 months)
- The ability to requisition land contributed to the rapid reconstruction of houses. Another contributory factor was the massive aid received from East European and Western sources (82 countries)
- Overall there was a balanced, diversified approach to shelter provision, which satisfied need, in spite of the exposure threat of cold weather, which came 3 months after the disaster
- The estimated damage total was £800 million, in which the overall cost of reconstruction is approaching the figure of £14,000 million[69]

The methodology used to evaluate the project involved summarising the strengths and limitations by reviewing the interview conversation records. Joseph Ashmore, an independent shelter consultant, also used this method in the *Shelter Project 2008*, *Shelter Project 2009* and *Shelter Project 2010* reports. The project team looked at case studies from Africa, Asia, Latin America and the Caribbean, and they carried out field research in most of the cases. For the areas they could not reach, they completed the reports based on information gained from their network contacts.

The main benefit of field research is to encourage pre-planning for reconstruction by communicating to people directly, and this can highlight problems that were not

[67] Ian Davis, "Tearfund Shelter and Reconstruction Standards," (2010).
[68] Professor Ian Davis is a British architect, who has specialised in Shelter, Reconstruction and Disaster Risk Reduction since 1972. He edited the first UN guidelines on "Shelter after Disaster" in 1981 and was a team member when developing its revision in 2009, as well as being one of the authors of Guidelines for the World Bank in Washington on "Housing Reconstruction following Disasters". He is currently a visiting professor in Disaster Management at Oxford Brookes and Kyoto Universities.
[69] Ian Davis, *Shelter after disaster* (Oxford: Oxford Polytechnic Press, 1978), 100.

visible through secondary resources. The common problem is that the evaluation standards can be subjective, depending on the consultant's experience. To address this issue, Davis stated at the CENDEP (Centre for Development and Emergency Practice) Shelter Conference 2010, at Oxford Brookes University, that professionals who have knowledge from policy to construction are urgently needed.[70]

After 30 years of experience in shelters after disaster, Davis concludes that the shelter should be able to provide protection from sun, cold, wind and rain; storage of belongings; protection of property; the establishment of territorial claims (ownership and occupancy rights); the establishment of a staging point for future action (including salvage and reconstruction, as well as social reorganisation); emotional security and the need for privacy; an address for the receipt of services (medical aid/food distribution etc.); shelter within commuting distance from employment; and accommodation for families who have temporarily evacuated their homes for fear of subsequent damage.[71]

Davis points out that researchers and evaluators are likely to be directed by their self-interests, which might influence the quality of the evaluation results. For example, after the earthquake in Haiti in 2010, thousands of NGOs and agencies gathered to provide humanitarian aid. However, only 30% of the agencies were needed, and the excess in help may have been a hindrance to the country.[72] According to the United Nations Resolution 2012 (2011), adopted by the Security Council at its 6,631st meeting on 14 October 2011, the Security Council acknowledges that Haiti continues to face significant humanitarian challenges, with more than 600,000 internally displaced persons still dependent on assistance for their basic survival, an ongoing cholera epidemic, and extreme vulnerability to natural disasters.[73]

The benefits of using disaster relief standards, such as the Tearfund Shelter and Reconstruction Standards, are their ease of use by volunteers or researchers without professional training backgrounds in disaster relief, and their ability to be adapted by many different sectors and used in several situations. However, it is important for agencies that use these guidelines to tailor them to their projects. It is also important for international agencies to work closely with local consultants during disaster

[70] ———, "What have we learned from 40 years' experience of Disaster Shelter?," in *CENDER (Centre for Development and Emergency Practice) Shelter Conference 2010* (Oxford2010).
[71] Ibid.
[72] Ibid.
[73] United Nations Security Council, "Resolution 2012 (2011) - Adopted by the Security Council at its 6631st meeting, on 14 October 2011," (2011), 1.

recovery projects, from the early planning stage to a later evaluation stage. This is because, as Davis states in an email with the author on 18 May 2012, “the market[74] is very slim in this subject, and getting thinner all the time due to agency cutbacks and the greater availability of much cheaper consultants from India and Bangladesh”.[75]

3.5.2.4 Post-Occupancy Evaluation of the Container Temporary Housing through Quantitative Surveys and Structured Interviews

FIGURE 3. 6. - FIGURE 3. 7. Container temporary housing – Onagawa, Miyagi; An exterior view[76]

Despite the availability of complex evaluation and analysis methods, less complicated surveys/questionnaires can also be useful and sufficient. Since the 2011 Tohoku earthquake (11 March, Tohoku, Japan), Shigeru Ban Architects have visited more than 50 evacuation facilities and installed over 1,800 units (2m×2m) of their Paper Partition System (Figures 3.8. and 3.9.), to ensure privacy.[77]

FIGURE 3. 8. - FIGURE 3. 9. Paper tubes in transportation; Paper Partition System in a stadium[78]

[74] The market indicates the agency market in disaster relief projects.
[75] Ian Davis, 2012.
[76] Shigeru Ban Architects, "Container Temporary Housing – Onagawa, Miyagi," (2011).
[77] ———, "Container Temporary Housing - Onagawa, Miyagi," http://www.shigerubanarchitects.com/SBA_WORKS/SBA_DRP/SBA_DRP_11/SBA_DRP_11.html (assessed 10 September 2012).
[78] Yasunori Harano, "Paper Partition System at Yamagata, Japan," (2011).

In the aftermath of the earthquake, Shigeru Ban heard that the town of Onagawa was having difficulty constructing sufficient temporary housing. Ban's research team found out that, although temporary housing was being deployed to the disaster areas, it was insufficient for the amount of housing required. Because most of the damaged coast areas were not on level terrain. Usually, temporary housing is only suitable for flatlands and, therefore, providing the required number of units was difficult. Ban Architects also found that the standard temporary houses issued by the government were poorly made, and without adequate storage space.[79] They proposed, in response, three-storey, temporary housing made from shipping containers, and installed built-in closets and shelves in all of the homes. By stacking containers in a checkerboard pattern, the system created bright, open living spaces between the containers and a market was built in the centre of the site because stores were not located in this neighbourhood and daily necessities were not easily accessible. The market provided a space for locals to open shops, and a lounge enabled people to buy fresh vegetables or gather together. The big tent made community events possible which, in turn, helped people to comfort each other after the earthquake. The project was completed on 1 March 2012, with help from volunteers and a donation fund. Ban's ground-breaking work has set a precedent for new government standards of evacuation facilities and temporary housing.


FIGURE 3. 10. - FIGURE 3. 11. An interior view of the temporary housing; A market in the centre of the site[80]

The Container Temporary Housing in Onagawa, Miyagi prefecture, had three types of plans – 19.8m^2, 29.7m^2 and 39.6m^2 – based on the arrangement of the containers. The 19.8m^2 plan is for one or two residents, the 29.7m^2 plan is for three to four residents and the 39.6m^2 plan is for more than four residents. To provide more space for storage, the Voluntary Architects Network (VAN) assembled shelves and installed them in each room. About 200 people gathered from all over the country to

[79] Shigeru Ban Architects, "Container Temporary Housing - Onagawa, Miyagi".
[80] ———, "Container Temporary Housing – Onagawa, Miyagi."

volunteer in Onagawa. The strengths of the project include: the short construction time, due to the usage of existing containers, which created the wide interval space between the containers, enabling parking areas, community facilities and family privacy; the placing of containers in a checkerboard pattern to create an open living spaces; buildings that provided excellent seismic performance in the case of more earthquakes; and the opportunity to use the building for permanent apartments if necessary.

FIGURE 3. 12. - FIGURE 3. 13. Shigeru Ban and VAN team in a meeting before carrying out surveys;[81] A VAN team member interviewing a resident with a survey[82]

The 20-strong VAN team took seven days to carry out the residential characteristics survey (4 to 10 March 2012). VAN released the survey report, entitled the *Improvement of Existing Temporary Housing*[83] online on 23 May 2012.[84] Their survey included four aspects: satisfaction with the dwelling; specific issues relating to, such as sound insulation performance, dwelling storage, air conditioning, and bathroom and kitchen facilities, the usage of meeting places; and the convenience of facilities, such as shops, playgrounds and transport. After the surveys and interviews with residents, the VAN team carried out small modifications and repairs in some households that reported problems.

Two lessons can be learnt from this case:

(i) It is not always the high-technology methods that are the most efficient for evaluation. In many cases, especially with post-occupancy evaluation, the

[81] VAN - Voluntary Architects' Network, "Residential Characteristics Survey Day 1," (2012).
[82] ———, "Residential Characteristics Survey Day 5 08 Mar 2012," (2012).
[83] Voluntary Architects' Network, "VAN - Voluntary Architects' Network," http://www.facebook.com/VoluntaryArchitectsNetwork (assessed 30 July 2012).
[84] The author used google translator online to obtain useful information from the report. For example, the author was able to understand the aspects that Shigeru Ban's team evaluated, including satisfaction with the dwelling, sound insulation performance, dwelling storage, air conditioning, bathroom/kitchen facilities, the usage of meeting places and the convenience of the facilities, such as shops, playgrounds and transport.

more effective method is to communicate with the users through informal interviews and questionnaires. The evaluators can use an unstructured interviewing strategy to interview professional groups, including researchers, architects, designers, event organisers, construction organisers and volunteer students. Unstructured interviews are conversational and can be used to obtain qualitative information, whereas structured interviewing can be used to obtain both quantitative and qualitative data and information. The structured interviews are based on specific questions and offer the interviewee a range of answers.

(ii) It is important for the designer to know how well the design has been received by users. Again, this case proves that evaluation is a part of the design process in the project cycle. In this case, it would be better for the designer of the project to organise the evaluation if it is the functional performance that is to be assessed.

3.5.2.5 Toolkits Developed by Save the Children

The Toolkits publication is a practical guide to planning, monitoring, evaluating and assessing impact, as developed by Save the Children UK. Save the Children is an international organisation that aims to help children in need and their work has had a significant impact around the world since being established in 1919. The Toolkits were first published in 1995, and the second edition was published in 2003. It states the underlying principles of a project and clarifies why planning, monitoring, review, evaluation and impact assessments are essential for developing plans, and how they are linked to decision-making. It outlines the pros and cons with respect to practical questions, and looks at them in more detail. On asking the question of how advocacy can be monitored and evaluated, it describes in detail the different tools, and lists strengths and weaknesses of each technique.

- Tool 1: Participatory learning and action (PLA)

The PLA is a qualitative research method that enables users to analyse their own situation instead of having it analysed by external bodies which may charge fees and cause delays. It was previously entitled Participatory Rapid Action (PRA). It has two variants – Rapid Rural Appraisal (RRA) and Rapid Assessment Procedures (RAP).[85] The methods of gathering and analysing information are through *secondary sources*, such as project reports and documented case studies, *direct observation*, such as interviews and focus group discussion, *ranking and scoring*, such as a tables of ranking to identify criteria for certain objects, and *construction of diagrams and maps*, such as social maps showing areas where groups of people live. PLA is most helpful with the participation of all concerned, and this is essential for the success of the work being proposed. PLA provides a good understanding of a community and its capacities, and the potential problems faced by those involved in the assessment, including community members. People involved in the assessment can include community members, local government officials and NGO staff. Unfortunately, the results are difficult for people outside the team to verify, because statistical methods are not used. Furthermore, the findings may not carry the same weight with decision-makers who seek quantitative data. [86]

- Tool 2: Surveys

Surveys can always be used in all kinds of evaluation to collect a broad range of quantitative and qualitative information. The three steps in carrying out a survey are: survey design, data collecting and data analysis. Using surveys in evaluation can provide the evaluator with precise and statistical answers to various defined questions. However, surveys are often designed to prove what the evaluator believes and, therefore, it is important to be critical when considering the conclusions.

- Tool 3: Logical framework analysis (LFA)

LFA was originally designed for the United States Agency for International Development (USAID) in 1969, and it has been adopted and developed by other agencies, such as the International Planned Parenthood Federation (IPPF) and the Department for International Development (DfID).[87] The LFA approach can be used by project beneficiaries or consultants after the programme has been designed, to analyse the logic of the relationship between its aim and the proposed activities. It is done by presenting the results in a table or matrix.[88] LFA helps planners to consider how they will monitor and evaluate the programme by identifying indicators at the

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[85] Louisa Gosling, Mike Edwards, and Fund Save the Children, *Toolkits : a practical guide to planning, monitoring, evaluation and impact assessment* (London: Save the Children, 2003), 93-213.
[86] Ibid., 212-13.
[87] Ibid., 222.
[88] Ibid., 223.

beginning, but it stresses a quantitative assessment rather than a qualitative approach, which may affect the development of the project.

- Tool 4: Cost-effectiveness analysis

Cost-effectiveness can be defined as the ability to achieve objectives at a reasonable cost. It can be calculated as *the cost per unit of service given* or *the cost per beneficiary*, which is done by dividing the cost of an activity by the quantity of its output, or by the number of beneficiaries. This is useful when comparing different possible ways of achieving the same objectives.[89] The cost-effectiveness analysis is useful for giving information to donors and project founders but, whilst it is important for project planning, it is often not relevant for social development projects.

- Tool 5: Strengths, weaknesses, opportunities and constraints (SWOC) analysis

This tool provides evaluators with a framework to analyse an existing situation. The "strengths" refer to "those things that have worked", "weaknesses" are "those things that have not worked so well", and "opportunities" and "constraints" are "the constraints that reduce the range of opportunities for change".[90] This is a good way of reviewing the project process; although, it is also important to give recommendations that summarise the lessons learnt through the evaluation system.

- Tool 6: Setting objectives

Setting objectives happens at the planning stage prior to a project. A useful method for this is the production of a problem tree and turning it into an objectives tree, firstly by writing down the problems and arranging the causal factors below and effects above, and, secondly, by establishing the links between the causal factors. Finally, each factor is transferred into an issue to address, which helps participants identify key questions and, therefore, find the answers. The challenge is how to use the results to compare evaluation findings against the objectives

- Tool 7: Example of evaluating participation

This method indicates the idea of self-evaluation. The basic steps in identifying indicators are:

[89] Ibid., 225.
[90] Ibid., 242.

1) Identify the common problems and successes of a programme.

2) State these as specific questions to be discussed in a group.

3) Define a range of answers on a scale of 0–3 to classify different situations.[91]

The strength of this evaluation is that groups can use this method to evaluate their own progress although, because the indicators are selected from an existing list, other important questions might be missed.

- Tool 8: Using consultants

The purpose of consultancy is to gain a wider view of the project quickly by conducting various tasks. Generally, the three steps of construction are identifying the right consultant, working as a team and carrying out the work after the consultant leaves. Consultancy costs more than self-evaluation but, it is a helpful way to undertake the evaluation efficiently.

- Tool 9: Programme or project visits

The purposes of project visits include discussing particular problems, sharing experiences, monitoring exercises and assessing progress. They offer good opportunities for people from different backgrounds to get involved in the on-going work. A visitor from outside the project can have a more objective view of the work which can be essential to the evaluation. One challenge is that of limited visiting time, wherein the visitors may only gain a superficial understanding of the work and this can make it too general to be useful in monitoring and evaluation.

- Tool 10: Presenting and sharing information: meetings, diagrams, video and theatre

Meetings, such as focus groups and small seminars, can be used to present the findings of an exercise to participants. Drawbacks can include difficulty in arranging a meeting that would have suitable timing for all.

Diagrams such as maps and charts can offer evaluators a clear visual image to enable them to understand the process of the project. They can minimise a large amount of written/gathered information into a smaller visual image, which can be a more convenient way to present the data results.

[91] Ibid., 254.

Video is an efficient tool for collecting, analysing and storing data. It also records the process of a project and shows the change over time, although its use may increase the project costs in terms of facilities. A good example of using video was during the Chengdu Hualin Elementary School's construction period. Postgraduate student Zhen Xiao, from Beijing University, China, filmed the process of this project from the beginning, when volunteers were arriving, until the opening ceremony. This short film *The Diary of the Paper House*, won the best film prize at The Third Student Video and Film Festival in China, but more importantly, it provided information for the evaluation of this project, and is helpful to other researchers.[92] This short film was used to identify interviewees for the research case study (see Chapter 4).

For development, theatre is a well-established means of communicating the feelings and viewpoints of different people, and how these views interact with each other.[93] It can be used in the form of workshops and discussion groups, and it is particularly successful with children and young people because it explores the problem by encouraging them to perform in front of an audience. However, it can be expensive and time-consuming.

- Tool 11: Training and development in planning, monitoring, reviews, evaluation and impact assessment

"Training and development needs to be part of a long-term strategy to develop skills and techniques that are integrated into the normal process for programme management."[94] It can help project managers to clarify the project development, thus identifying ways of approaching the problems. It is important to remember that PME (planning, monitoring and evaluation) is a practical experience rather than an academic exercise, and projects should be assessed in terms of its functionality.

- Tool 12: Stakeholder analysis

"A stakeholder analysis is a process for identifying stakeholders, understanding how they relate to an activity, their interests and needs, in order to identify opportunities and potential threats."[95] Stakeholders are the people who affect the projects directly.

- Tool 13: Frameworks to help analyse the advocacy process

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[92] Zhen Xiao, "The Diary of the Paper House," (2008).
[93] Gosling, Edwards, and Save the Children, *Toolkits : a practical guide to planning, monitoring, evaluation and impact assessment*: 290.
[94] Ibid., 294.
[95] Ibid., 302.

This tool contains three sections: monitoring and evaluating policy change and implementation, monitoring and evaluating the capacity for advocacy, and monitoring and evaluating advocacy networks and movements. The first section requires the evaluators to decide what to monitor and then to identify advocacy indicators. The second section looks at frameworks developed to help understand changes in the ability of people, organisations and society to become involved in advocacy work. The third section uses a framework developed by The Open University to stress different degrees of collaboration, and gives precise definitions for words that tend to be used very loosely.

- Tool 14: Frameworks for developing monitoring and evaluation questions in emergency situations

The final tool follows a list of minimum standards and indicators for several key sectors covered by most disaster responses. These can be used to assess how effectively a programme is addressing problems in these sectors.

This Toolkit is a collection of analysis methods that can be useful in evaluating projects that are designed to help children in need. The methods include both quantitative and qualitative research strategies and the purpose relates directly to this chapter, in that it presents a list of analysis and evaluation methods that have potential value in evaluating demountable buildings, regarding data collection techniques and research methodology.

3.5.2.6 ASPIRE (A Sustainability Poverty and Infrastructure Routine for Evaluation)

ASPIRE (A Sustainability Poverty and Infrastructure Routine for Evaluation) is a computer programme that that developed from the SPeAR® software platform by Arup and Engineers Against Poverty, supported by the Institution of Civil Engineers (ICE) R&D Enabling Fund. It carries out the assessment within four sectors: institutions, environment, economics and society. ASPIRE was developed by EAP and Arup in recognition of the fundamental role infrastructure plays in tackling poverty and contributing to sustainable development. Access to water, energy, healthcare, education and markets enables communities to move beyond survival to self-sufficiency and to participate in society. ASPIRE was developed to help those funding, commissioning and implementing infrastructure projects to consider a wider range of issues and stakeholder concerns. The software has been designed to be operated and understood by programme and project managers, engineers, and monitoring and evaluation specialists who may not have specialist knowledge of sustainable development or poverty reduction through their projects, programmes and interventions. ASPIRE has been developed so that it can be used usually to monitor and evaluate project performance and support informed decision-making throughout the project life-cycle. It can be used to conduct a baseline assessment, gap analysis, or identify key performance indicators. According to the user manual, ASPIRE can be used during the design stage to compare and assess the benefits and limitations of various design options, identify key risk areas, guide decision-making and stakeholder participation, or assess the implications of design changes. It can also be used at a later stage, during operation and after completion, which can help organisations to learn approaches to future projects.[96]

TABLE 3.1. The four assessment sectors of the ASPIRE software[97]

Institutions	Environment	Economics	Society
Structures	Air	Equity	Population
Skills	Land	Livelihoods	Culture
Policies	Water	Macro	Stakeholders
Reporting	Biodiversity	Viability	Services
	Energy		Health
	Materials		Vulnerability

ASPIRE can be easily used and understood by professionals from different backgrounds. It follows the steps of inputting the data, grading and presenting the results graphically. For example, in Figure 3.14, once the user chooses to put data and notes into the *Structure* section, a list of considerations will be proposed; including national/local government effectiveness, project - government coordination, corruption, civil society and rule of law.

[96] ASPIRE was deigned to evaluate poverty development in relation to the project process, while not specifically focusing on a post-occupancy evaluation. Therefore, it was not suitable to apply ASPIRE directly to evaluate the functional performance of the case studies of the thesis since the research aim was to deliver a post-occupancy evaluation method instead of a pre-occupancy evaluation or monitoring method.
[97] ARUP, "ASPIRE A Sustainability Poverty and Infrastructure Routine for Evaluation, User Manual," http://www.oasys-software.com/media/Manuals/Latest_Manuals/aspire1.1_manual.pdf.

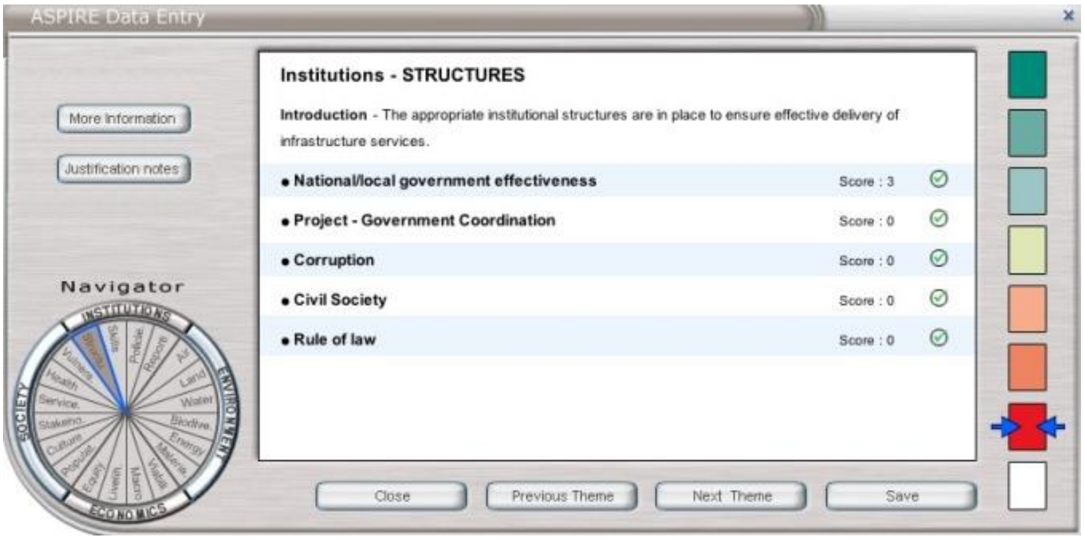


FIGURE 3. 14. Data entry dialogue screen[98]

The next step is to enter the data by clicking on each sub-theme heading to bring up the specific sub-theme scoring screen (Figure 3.15.). The user selects a score from 1 to 5, where 1 represents the worst case and 5 represents the best case.

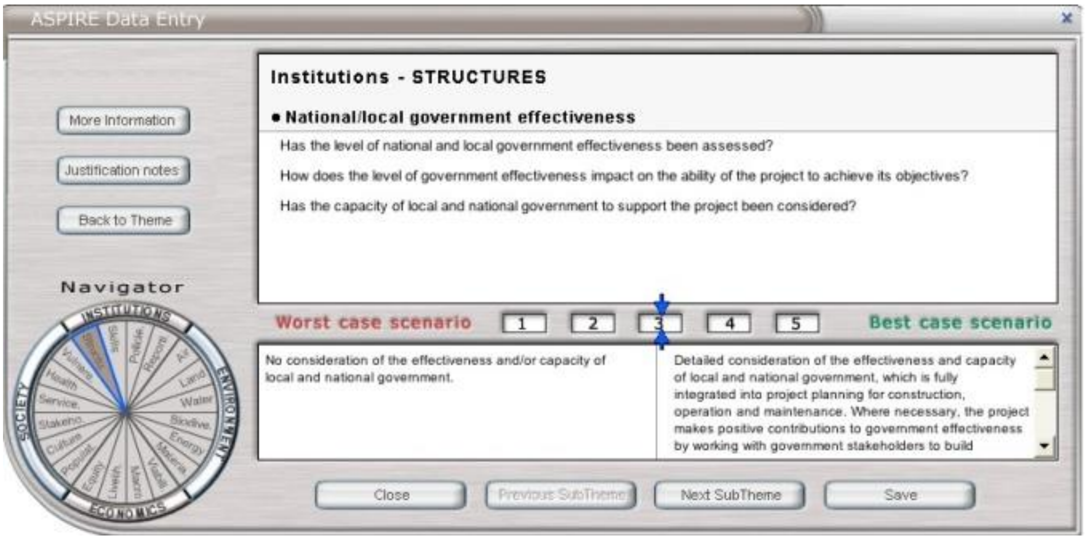


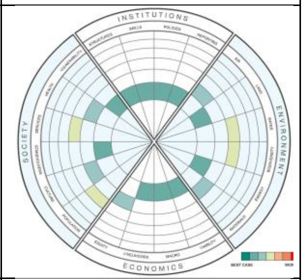
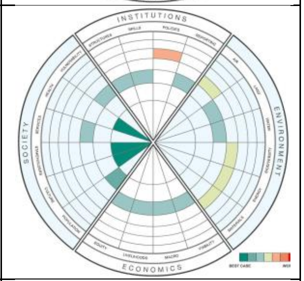
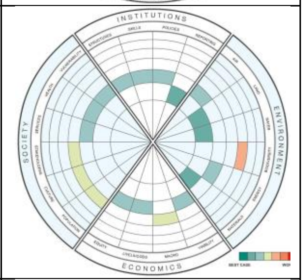
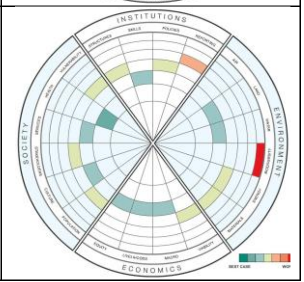
FIGURE 3. 15. Sub-theme scoring screen[99]

Following these steps, each aspect of the four sectors will be given a mark. The closer to the centre of the evaluation wheel, the better the project is. The software users can view the visualised evaluation results easily, and can save the data into an Excel report for further analysis. ASPIRE has been utilised worldwide, such as Arup Infrastructure Gautrain Rapid Rail Link, Gauteng, South Africa; Maji Na Ufanisi Community Water and Sanitation Project, Nairobi Kenya; Sabre Trust Kindergarten Building, KEEA District Ghana; Belgian Red Cross Tsunami Reconstruction Housing

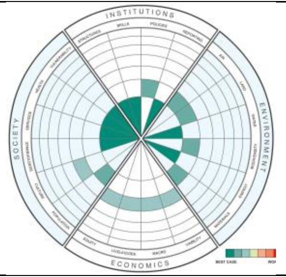
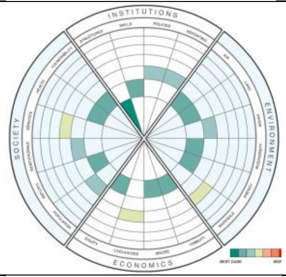
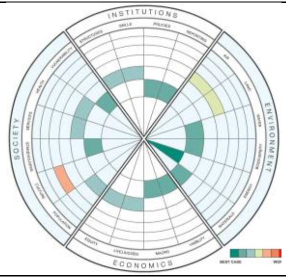
[98] Ibid.
[99] Ibid.

Project, Sri Lanka; Arup Angwin Eco Village, California, USA; InfraCo Africa, Chyanyanna Irrigation Pilot Project Kafue District, Zambia and Arup Greenfield Site, Bristol, UK. The following table shows the comparison of the results of each case study.

TABLE 3.2. A comparison of the ASPIRE case studies[100]

Project	**Assessment**				**Diagram**
	Institutions	**Environment**	**Economics**	**Society**	
Arup Infrastructure Gautrain Rapid Rail Link, Gauteng, South Africa[101]	A record of good public relations – opened to inspection by the public during the development process	Encourages new development; impact on water systems through the disposal of water during construction; trees were felled	Increases employment opportunities; encourages local business	A neutral stance on the project's impact on community cohesion along the transport corridor	
Maji Na Ufanisi Community Water & Sanitation Project, Nairobi, Kenya[102]	The project strategically aligns with the aims of a number of government initiatives; a lack of legitimacy of the slums	Demonstrates consideration of the impact on the local environment; efficient use of raw materials prevented wastage and reduced costs	Successful in raising sufficient funds from the first project; encourages micro enterprises	A good example of cross-tribal cooperation	
Sabre Trust Kindergarten Building, KEEA District, Ghana[103]	The project is strongly linked with the local community involving regional and national stakeholders	Water and land themes feature strongly, owing to the infiltration of the drainage system; no environmental risk plan available	Uncertain if funds will continue to be available; equitable distribution of benefits to the community	Free pre-primary educational and community facilities	
Belgian Red Cross Tsunami Reconstructio n Housing Project, Sri Lanka[104]	Good performance in the Skills theme; improvement could be made in the Policies and Structure theme	No environmental management plan; no sufficient consideration of energy efficiency in construction	Creates local jobs; cost-effectively maintained by using local resources; lack of assessment of risks and future costs	Improves the quality of life for local communities; sometimes tension between community groups	

[100] ———, "ASPIRE A Sustainability Poverty and Infrastructure Routine for Evaluation, Research and Development," http://www.engineersagainstpoverty.org/_db/_documents/ASPIRE_-_R&D_Report.pdf (assessed 30 January 2013).
[101] The assessment was the technical review for the development of the Gautrain Link at Arup.
[102] A post-project evaluation undertaken by Arup staff and the local community.
[103] First assessment was carried out as a gap analysis; second assessment was carried out during the appraisal stage.
[104] Assessment carried out as a post-project evaluation by Belgian Red Cross.

Arup Angwin Eco Village, California, USA[105]	Effective engagement developed for stakeholders; an informative website was also created	Re-use and development of brownfield land; sufficient in using recycled wastewater such as rainwater and spring water	A lack of planning for local sourcing and employment creation	The project has good impacts on the community, especially on vulnerable groups	
InfraCo Africa, Chyanyanna Irrigation Pilot Project, Kafue District, Zambia[106]	The projects supports the cooperation of local stakeholders; lack of financial performance tracking system	Renewable energy – solar power was incorporated into the project	Sophisticated financial models are available to use and all debt is professionally managed	Gender equity considered; transport links are limited and restricted to public mini-buses and expensive vehicle services	
Arup Greenfield Site, Bristol, UK[107]	Open dissemination of information to stakeholders; effective communion through media	Benefitting from onsite wind turbines; poor air quality because the site is close to a motorway	Created opportunities for new local businesses; provision of jobs for local people may not be equally distributed to the surrounding communities	A fully resourced consultation scheme; strong local community involvement; gender consideration needs further improvement	

Although ASPIRE can produce clear evaluation diagrams that help users to understand their project from a relatively comprehensive aspect, as well as offering some recommendations, it is still unclear to the users at what point the evaluation should be carried out in order to achieve the most effective results. ASPRIRE is also ambiguous about which projects the software can be used for or whether it is suitable for all scales. The software is, therefore, currently suitable for offering simple analysis with a full focus on qualitative results.

3.5.2.7 Monitoring and Evaluating Post-Disaster Recovery Using High-Resolution Satellite Imagery

Researchers from Cambridge University, ImageCAT Ltd and Cambridge Architectural Research Ltd, have used remote sensing and field surveys to identify indicators for measuring, monitoring and evaluating post-disaster recovery,[108] as well as exploring the use of new technologies, including GPS-based field techniques

[105] Assessment carried out during the identification stage by staff from Arup San Francisco team.
[106] The assessment was carried out during the monitoring process by a private infrastructure development group with local stakeholders.
[107] The assessment was applied at the identification stage by Arup staff in the Bristol office.
[108] Post-disaster recovery can be seen as an attempt to bring a post-disaster situation to a level of acceptability through the reflection of damage and disruption, and has been implemented upon an urban system's built environment, people and institutions.

and Satellite Imagery Analysis. The research team includes Michael Ramage, Daniel Brown, Keiko Saito and Torwong Chenvidyakarn from the Department of Architecture, Cambridge University Beverley Adams and John Bevington from ImageCAT Ltd. Ashtead, UK and Robin Spence and Steve Platt from Cambridge Architectural Research Ltd. The two outputs produce a standardised approach to monitoring long-term recovery and developing a user guide for aid agencies on how to use these tools.

Remote Sensing M&E (monitoring and evaluation) is a new scientifically-based technique to help donors and governments answer key challenges in effectively monitoring and evaluating post-disaster recovery and reconstruction.[109] The project team is funded by the EPSRC (Engineering and Physical Sciences Research Council), and includes Cambridge University, ImageCat, Inc and Cambridge Architectural Research. The research method involves using remote sensing on recent post-disaster case studies, such as the Indian Ocean tsunami, the Pakistan earthquake of 2005, and the 2008 earthquake in Wenchuan, Sichuan, with the cooperation of Chongqing University, China.

During the monitoring and evaluation of the removal and construction of buildings in Ban Nam Khem, Thailand, following the devastating 2004 tsunami, housing performance indicators were obtained from analysing a time-series of satellite images, collected before the tsunami, immediately afterwards and in the months and years following. As recovery took place, progress was evaluated by tracking the year-by-year increase and comparing the total number of dwellings with the pre-disaster state.[110]

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[109] The Recovery Project Team, "Disaster Recovery Monitoring & Evaluation," in *CENDER (Centre for Development and Emergency Practice) Shelter Conference 2010* (Oxford2010).
[110] Ibid.

FIGURE 3. 16. - FIGURE 3. 18. Transitional Shelter: Ban Nam Khem, Thailand (24 June 2002); 2 January 2005; 28 February 2006[111]

The satellite imagery offers a systematic, independent and replicable framework for recovery monitoring and evaluation. The users can build up a comprehensive picture of recovery, or pick and choose specific indicators of interest. Satellites can access hard-to-reach or high-risk locations whilst avoiding security risks to field teams. This is particularly important for disaster recovery as aftershocks and tsunamis usually often follow earthquakes. The resulting data from satellite imagery can be transferred to a database, table or graphical representation, depending on the clients' needs. The development of in-house capabilities for monitoring and evaluating recovery with remote sensing requires technical expertise in satellite image acquisition, processing and interpretation. Specialist GIS and image analysis software is needed, which may cost up to $10,000[112] and therefore, it is not suitable for a wide range of uses in developing or less developed countries where the frequency of natural disasters is high but the ability to deal with disasters is relatively low. As such, new technologies, such as GIS and imagery analysis, can be especially useful for research in demountable buildings because the travelling tracks of the building can be monitored through sensing systems bringing benefits to visualisation, mapping and accuracy.

[111] Keiko Saito Daniel Brown, Robin Spence and Torwong Chenvidyakarn, "Indicators for Measuring, Monitoring and Evluating Post-Disaster Recovery," in *2009 Joint Urban Remote Sensing Event* (Shanghai2009).
[112] The Recovery Project Team, "Disaster Recovery Monitoring & Evaluation.".

3.5.3 Methods in Environmental Assessment

In order to promote sustainable, high quality buildings and built environments, a variety of organisations, research centres and commercial companies have developed analytical methods that incorporate design thinking and architectural assessment. They have been extremely important in reducing environmental impacts and promoting green alternatives. In order to learn from their practical methodology and develop a tool to evaluate demountable buildings, methods in environmental assessment, including ISO 14001:2004 Environmental Management Systems, using sensing systems for waste management, IES (Integrated Environmental Solutions) and DesignBuilder and CASBEE (Comprehensive Assessment System for Built Environment Efficiency) for Temporary Constructions Tool – 1TC, will be discussed.

3.5.3.1 ISO 14001:2004 Environmental Management Systems

The ISO (International Organization for Standardization) is the world's largest developer and publisher of international standards. ISO Standards provide a reference framework with a common language to products' suppliers and their customers.[113] It has developed over 19,000 international standards on a variety of subjects, including assessments for products, services and buildings. For example, *ISO 13822:2010 Bases for Design of Structures – Assessment of Existing Structures*, in 2009, has been used for assessing the safety and serviceability of existing structures (including buildings, bridges and industrial structures). ISO members are non-governmental, and they are responsible for making all strategic decisions. They meet for an annual general assembly where the proposals put to the members are developed by the ISO Council. The council is drawn cross the membership, and resembles a board of directors. The ISO has a long history in developing reliable principles for use by companies, factories and other industries.

Based on the ISO online data, 2% of the standards are provided for building construction each year, although other standards, such as engineering technology, transportation and material technology, also contains useful information for demountable building components. ISO standards can be used as an important reference for demountable building evaluation, and, the Portakabin Group,[114] – the

[113] ISO, http://www.iso.org/iso/support/faqs/faqs_general_information_on_iso.htm (assessed 1 October 2010).

[114] The Portakabin Group is based in York, England, and has designed and manufactured modular and portable buildings for sale or hire at the 250,000m^2 Portakabin production facility.

first modular building company to commit to meeting the challenges set out in the traditional construction industry's Major Contractors Group Sustainability Charter, has gained recognition for high standards of environmental management and commitment to on-going environmental responsibility, with accreditation to the ISO 14001[115] International Standard.

The aim of ISO 14001:2004 is to identify all potential environmental effects of a company's operations, and to develop and implement a system that limits environmental effects to set targets.[116] ISO 14001 specifies the necessary requirements for an environmental management system to enable an organisation to develop and implement a policy and objectives that take into account legal requirements, information about significant environmental aspects, and other requirements to which the organisation subscribes. It applies to those environmental aspects that the organisation identifies that it can control and those it can influence. It does not state specific environmental performance criteria, and it is applicable to any organisation that wishes to:

a) establish, implement, maintain and improve an environmental management system;
b) assure itself of conformity with its stated environmental policy;
c) demonstrate conformity with this International Standard by
    - making a self-determination and self-declaration, or
    - seeking confirmation of its conformance by parties having an interest in the organisation, such as customers, or
    - seeking confirmation of its self-declaration by a party external to the organisation, or
    - seeking certification/registration of its environmental management system by an external organisation.[117]

All the requirements in this standard are intended to be integrated into any environmental management system. The recognition from ISO 14001 is an authoritative approval of a commitment to sustainability through energy-saving and environmental programme which reduce energy and resource consumption, minimise waste and cut carbon emissions.

[115] ISO 14001 was prepared by Technical Committee ISO/TC 207, Environmental management, Subcommittee SC 1, Environmental management systems. The ISO 14001:2004 is the second edition, which cancels and replaces the first edition – ISO 14001:1996 – which has been technically revised.
[116] British Standards Institution, "Environmental Management Systems - Requirements with Guidance for Use (ISO 14001:2004)," (British Standards Institution, 2005).
[117] Ibid., 1.

3.5.3.2 Using Sensing Systems for Waste Management

The MIT SENSEable City Laboratory has designed an active, self-reporting tag to follow 2,000 waste objects to map the journey of wasted objects, reveal the disposal process of everyday objects and create awareness in waste management.[118] The Lab aims to investigate and anticipate how digital technologies are changing the way that people live and the implication on an urban scale. Director Carlo Ratti founded the SENSEable City Lab in 2004, within the City Design and Development group at the Department of Urban Studies and Planning MIT, in collaboration with the MIT Media Lab. Their projects include: Real Time Rome (2006), The Wireless City (2007), Digital Water Pavilion (2008), Trash Track (2009), Flyfire (2010), Trans of Data (2011) and Future Olympic Village (2012).

The Trash Track project team includes Santi Phithakkitnukoon, Malima Isabelle Wolf, Dietmar Offenhuber, David Lee, Assaf Biderman and Carlo Ratti and it started in September 2009, initially enlisting volunteers in New York, Seattle and London who agreed to have their rubbish electronically tagged using wireless location markers. Trash Track used thousands of small, location-aware tags which were attached to all the trash items and monitored in the Lab as they travelled through the city's waste management system. Different from using high-resolution satellite imagery for monitoring and evaluating post-disaster recovery, Trash Tack's tag was based on GSM (Global System for Mobile Communications) cellular phone technology, and estimated the tag position using the Cell-ID triangulation technique, which measures signal strength from each cell phone tower in sight of the device and compares it to the geographical positions of the towers.[119] Cellular signal can be picked up inside buildings without requiring an unobstructed sky view, although it is not as accurate as a GPS system.[120] All the tags were waterproofed and covered with a one-inch thick foam for protection. The trash included cell phones, E-waste (such as computer equipment), glass, household hazardous waste (such as fluorescent bulbs and rechargeable batteries), metals, paper, plastic bottles, plastic-coated paper (such as milk cartons and coated paper cups) and textiles.[121] Items that were smaller than the tag were not considered for the research. The tracking device contained

[118] 1,152 traced objects were retained for analysis.
[119] Malima Isabelle Wolf Santi Phithakkitnukoon, Dietmar Offenhuber, David Lee, Assaf Biderman, Carlo Ratti, "Tracking Trash,"(2012), http://senseable.mit.edu/papers/pdf/2012_Phithakknitnukoon_TT.pdf (assessed 6 September 2012).
[120] Ibid.
[121] Ibid.

lithium batteries and other hazardous waste, thus, organic trash items were excluded in order to prevent potential contamination of composting sites.[122]


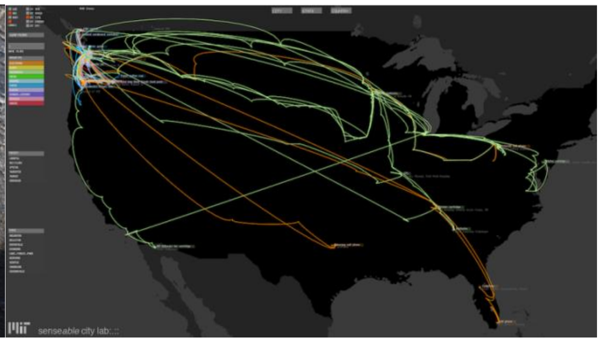

FIGURE 3. 19. - FIGURE 3. 20. First generation of trash tags;[123] Composite map of the recorded traces[124]

After analysis, the Lab concluded that there were five destinations for trash: landfill; recycling; special; transfer; and transit. It was also noted that "more emphasis should be placed on Household Hazardous Waste (HHW) in terms of better informing people about its disposal".[125] The results allowed the Lab to build upon on its previous work in the development of sensors and mobile technologies radically transform for understanding of cities. This is an ongoing project, and interested parties are able to view the items' movements online as well as visit exhibition in Seattle's Public Library and at the Architectural League in New York.[126]

It can be argued that, if the journey of trash can be mapped, the travelling path of demountable buildings can also be revealed. With current evaluation methods, a substantial amount of data in the form of transportation time, deployment time, and the distance of transportation is lost, because designers and builders pay little attention to the data's significance. The Lab's sensing system could be used to trace each building or structural component, and, as a result, the path and time of "travelling" would be clearly identified through monitoring the tracks in the computer. This would help to analyse the construction, exhibition and deployment process in order to decide how to achieve the maximum benefits from demountable buildings and other types of moveable architecture. The results could help to establish the pros and cons of whether to reuse the same components or recycle them, depending on the transportation costs and time. The data provided would also

[122] Ibid., 3.
[123] The MIT SENSEable City Laboratory, "The Trash Tag," (2009).
[124] ———, "Composite Map of the Recorded Traces," (2009).
[125] Santi Phithakkitnukoon, "Tracking Trash". 8.
[126] SENSEable City Lab, "Trash Track," http://senseable.mit.edu/trashtrack/ (assessed 19 July 2012).

be used to provide guidance for answering questions such as what transportation method to choose after the building is dismantled.

The Lab's associate director, Assaf Biderman, argues that the idea is potentially valuable for modular buildings in architectural research. On the other hand, it might not be useful for project clients because they normally choose the materials and designers that are available in the local area. However, Biderman also emphasised that their tracking technology works anywhere in the world, and they are able to monitor the tags in the Lab wherever the tag is, as long as the battery in the tag has not run out.[127]

3.5.3.3 IES (Integrated Environmental Solutions) and DesignBuilder

IES develops software simulation tools that assist architects, engineers, facilities managers and those involved in the development and management of building design to create healthier built environments. The IES software includes VE-Ware, VE-Toolkits, VE-Gaia and VE-Pro, and covers master-planning, concept design, scheme design, detailed design, and completion in-use. The IES is often used by building design and consultancy firms who are specialists in green buildings. Apart from software packages, IES also offers consultancy and training courses for individual trainees who wish to obtain an IES Virtual Environment Training Certificate.[128]

Similar to IES, DesignBuilder creates rapid building modelling for dynamic energy simulation. DesignBuilder is a unique software tool for creating and accessing building designs. It has been specifically developed to be used effectively at any stage of the design process, from the concept, where only a few parameters need to capture the building design, to much more detailed building models for established designs.

DesignBuilder is suitable for use by architects, building services engineers, energy consultants and university departments. Some typical uses are: evaluating a range of façade options for the effects on overheating, energy use and visual appearance; checking for optimal use of natural light; modelling lighting control systems and calculating savings in electric lighting; calculations of temperature, velocity and pressure distribution in and around buildings using CFD; visualisation of site

[127] Assaf Biderman, September 4 2012.
[128] IES (Integrated Environmental Solutions), http://www.iesve.com/ (assessed 27 July 2012).

layouts and solar shading; thermal simulation of naturally ventilated buildings; HVAC design, including heating and cooling equipment sizing; and communicating aid at design meetings and for teaching building energy simulations.[129]

Both IES and DesignBuilder are computer software packages that can be utilised by building consultants for energy analysis and to obtain accurate environmental performance data. The data can also be used as a part of environmental performance assessments in order to achieve certifications such as BREEAM[130] and LEED[131].

As Matthew Carmona et al. state: "New, highly specialised technology associated with state-of-the-art visualizations of projects mean that – except for a few specialists – few people understand precisely how the data is manipulated. As a consequence, few can access the information to verify the simulation's accuracy."[132] Although new technology has offered the opportunity to make information more accessible, designers and building consultants need to realise the advantages and disadvantages that a computer can play in the design and evaluation process of each project. It is important that developments in technology help designers and building consultants to engage more persuasively with the end-users in decision-making, especially in the evaluation process.

[129] DesignBuilder, http://www.designbuilder.co.uk/ (assessed 27 July 2012).

[130] BREEAM is a measurement rating system for green buildings that was established in the UK by the Building Research Establishment (BRE) in 1999. It aims to provide a credible, independently assessed sustainability label for building, recognition of a building's sustainability credentials, a driver to stimulate demand for sustainable buildings, and assistance to clients and designers in mitigating the life-cycle impacts of buildings. The typical process of undertaking a BREEAM Assessment comprises a number of key stages. These key stages are: deciding to carry out a BREEAM assessment, appointing a BREEAM assessor, appointing an accredited professional (AP), carrying out the pre-assessment, registering the project, carrying out the design stage assessment and undertaking the post-construction stage assessment.

[131] LEED is an internationally recognised green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO_2 emission reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

[132] Carmona et al., *Public Places Urban Spaces : The Dimensions of Urban Design*: 354.

3.5.3.4 CASBEE (Comprehensive Assessment System for Built Environment Efficiency)

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) is a method for the evaluation and rating of the environmental performance of buildings, developed by the Japanese Sustainable Building Consortium (JSBC) and Institute for Building Environment and Energy Conservation (IBEC).[133] It is a comprehensive assessment of the quality of a building, evaluating features such as interior comfort and scenic aesthetics in consideration of environmental practices that include using materials and equipment that save energy or achieve smaller environmental loads. The CASBEE assessment is calculated and ranked on five grades: Excellent (S), Very Good (A), Good (B^+), Fairly Poor (B^-) and Poor (C).[134] Each rank corresponds to the assessment expressions, and is ranked as a number of stars for clarity. The Assessment Results Sheet presents assessment results for each category as radar charts, bar graphs and numerical data for Q (Quality: built environment quality) and LR (environmental load reduction of the building). The BEE (Built Environment Efficiency) result is also presented numerically and graphically, giving a comprehensive grasp of the environmental characteristics of the evaluated building.[135]

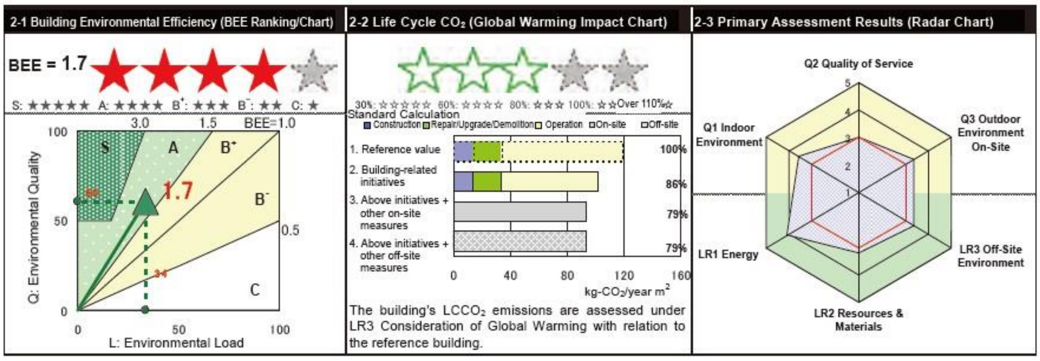

FIGURE 3. 21. Building Environmental Efficiency (BEE Ranking/Chart), Life Cycle CO_2 (Global Warming Impact Chart), Primary Assessment Results (Radar Chart)[136]

[133] The Japanese Sustainable Building Consortium (JSBC) and Institute for Building Environment and Energy Conservation (IBEC) have produced sixteen technical manuals, including: CASBEE for Detached House (for New Construction), CASBEE for Detached House (for Existing Building), CASBEE for New Construction (English version available), CASBEE for Existing, CASBEE for Renovation, CASBEE for Heat Island Relaxation, CASBEE for Temporary Construction, CASBEE for New Construction (Brief version), CASBEE for Existing Building (Brief version), CASBEE for Renovation (Brief version), CASBEE for Urban Development (English version available), CASBEE for Urban Development (Brief version), CASBEE for Urban Area + Buildings (English version available), CASBEE for Property Appraised (English version available), CASBEE for Market Promotion (temporary version with English version available) and CASBEE for Cities. The author has used CASBEE for New Construction and CASBEE for Temporary Construction in this thesis to discuss the principles of CASBEE and what can be learned from it.

[134] Japan Sustainable Building Consortium (JSBC), "CASBEE for New Construction." (2010), http://www.ibec.or.jp/CASBEE/english/download.htm (assessed 20 July 2012).

[135] Ibid., 16.

[136] Ibid., 8.

According to the CASBEE for New Construction guide, the assessment is suitable for both non-residential buildings (offices, school, retailers, restaurants, halls, factories) and residential buildings (hospitals, hotels and apartments).[137] The assessment can examine the whole environmental quality of the whole building, including indoor environment (sound environment, thermal comfort, lighting and illumination, air quality), quality of service (service ability, durability and reliability, flexibility and adaptability), and outdoor environment on site (preservation and creation of biotope, townscape and landscape, and local characteristics and outdoor amenities).[138]

As an extension to CASBEE for New Construction, CASBEE for Temporary Construction's Tool – 1TC – was developed for evaluating temporary buildings constructed specifically for short-term use, such as Expo pavilions. Buildings of this type have short-term lifecycles and, therefore, consideration must concentrate largely on material use and recycling in the construction and the demolition phases. The scoring criteria and weighting reflect all features of temporary buildings. In an email to the author on 30 April 2012, Nobufusa Yoshizawa, the Secretary of Japan GreenBuild Council/Japan Sustainable Building Consortium, states that it requires the CASBEE-NC manual to understand the method of assessment in the CASBEE for Temporary Construction, and there is no plan to translate this document into English.[139]

According to the Institute for Building Environment Energy Conservation (IBEC), the CASBEE evaluation method is suitable for all kinds of buildings (offices, schools, store shops, restaurants, hotels, meeting places, hospitals and clinics, factories, housing complexes) that will typically be used for no longer than five years.[140]

[137] Ibid., 14.
[138] Ibid., 18.
[139] Nobufusa Yoshizawa, 2012.
[140] Institute for Building Environment Energy Conservation, "CASBEE (Comprehensive Assessment System for Built Environment Efficiency) for Temporary Constructions Tool – 1TC," (2008), 2.

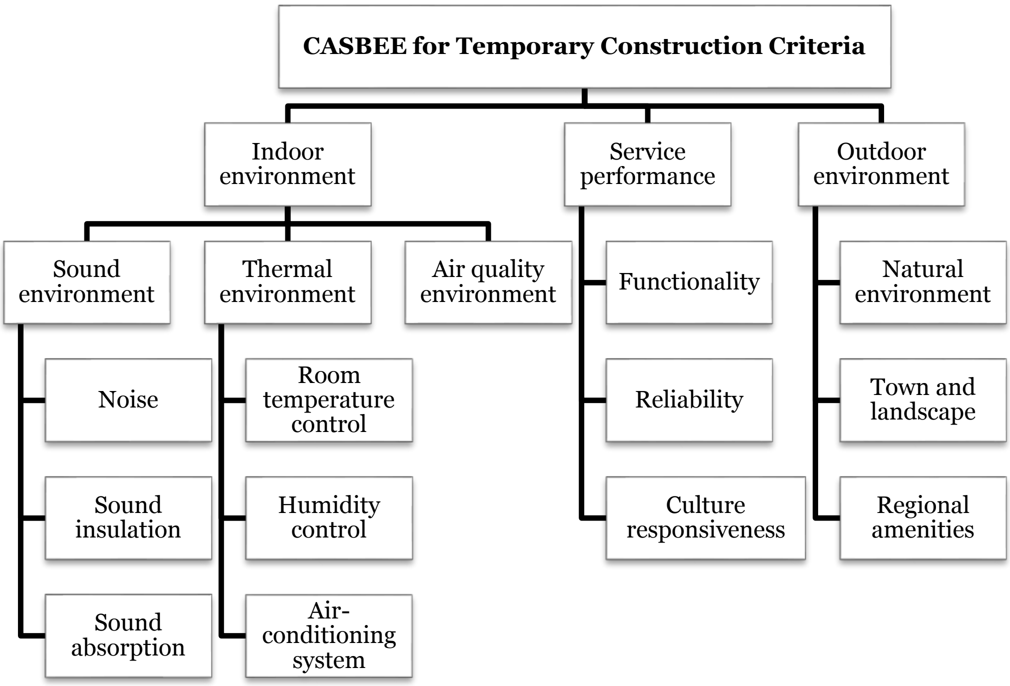

FIGURE 3. 22. CASBEE for Temporary Construction Criteria[141]

By December 2011, 193 buildings had been certified by CASBEE.[142] CASBEE has been successfully applied to two large-scale, demountable buildings: The Japan Pavilion Nagakute[143] and the Japan Pavilion Seto, both exhibited during the Expo 2005[144] in Archi, Japan.

Since 1990, when the United Kingdom established the first environmental building assessment system, many other countries have adapted or created their own rating systems specific to their climates and cultural values. In addition to LEED, BREEAM, the European Eco-Management and Audit Scheme, CASBEE and The Cradle to Cradle Certified[CM] programme,[145] there are many other sustainable building rating systems that have been operated by building consultants for evaluating both

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[141] Ibid., 5-7. Figure 3.22 was formed by the author based on the information obtained from a computer-based translator.

[142] Japan Sustainable Building Consortium (JSBC) Japan GreenBuild Council (JaGBC), "CASBEE Certified Buildings," http://www.ibec.or.jp/CASBEE/english/certified_bldgs.htm (assessed 6 September 2012).

[143] The 2005 World Exposition was held around the central theme of "Nature's Wisdom" in Aichi Prefecture, Japan. The Japan Pavilion Nagakute was constructed using eco-friendly technology. The timber connecting system, using bamboo connectors, was adapted to the structural timber connection in this pavilion. Energy consumption was reduced by the bamboo cover cage as a sunscreen, the bamboo grass green wall and bamboo roof tiles as insulation members. After the Expo 2005, the timber members obtained from the dismantled building were sold by internet auction for reuse.

[144] The 2005 Expo was held in Seto City, Nagakute Town and Toyota City in Aichi Prefecture in Japan.

[145] The Cradle to Cradle Certified[CM] programme was founded in 2005 by MBDC (McDonough Braungart Design Chemistry). The programme provides guidelines for companies that follow the Cradle to Cradle framework, which focuses on using safe materials that can be disassembled and recycled as technical nutrients or composted as biological nutrients. It provides certifications for all product types and, currently, it does not provide any certification to businesses or buildings. There are four levels of product certification: Basic, Silver, Gold and Platinum.

residential and commercial buildings.Linda Reeder concludes that a list of international recognised rating systems include Green Globes®, Energy Star®, the National Green Building Standards, Green Star, Hong Kong Building Environmental Assessment Method (HK-BEAM), Esrudama's Pearl Rating System and SBTool.[146]

Marita Wallhagen and Mauritz Glaumann, from the Department of Technology and Built Environment, University of Gävle, Sweden, discovered through research that the number of environmental assessment tools for building is increasing rapidly, with different assessment tools influencing the consequences.[147] In order to examine how different assessment tools influence the evaluation results, they selected three environmental assessment tools to examine the same residential building. They applied LEED-NC (New Construction), CSH (Code for Sustainable Homes) and EcoEffect 2006 to the same case study, which was a residential building with 32 apartments in Grönskär, Stockholm.[148] Wallhagen and Glaumann's research indicates that, although environmental assessment tools are normally marked as being at the frontline of promoting so-called sustainable building, these tools have different geographical contexts due to varying conditions and building cultures, and variations in the assessment tools can influence the design of a sustainable building.[149]

The use of technology and computer software can help to create an increased awareness of design and facilitate reactions to it. Although new technology has offered the opportunity to make information more accessible and comprehensible, designers need to appreciate the many roles that a computer can play in the design process, as well as the advantages and disadvantages of the computer for each task.

[146] Linda Reeder, *Guide to Green Building Rating Systems : Understanding LEED, Green Globes, Energy Star, the National Green Building Standard, and More* (Hoboken, N.J.: Wiley, 2010), 203-09.
[147] Marita Wallhagen and Mauritz Glaumann, "Design Consequences of Differences in Building Assessment Tools: A Case Study," *Building Research & Information Building Research & Information* 39, no. 1 (2011): 17.
[148] Ibid.
[149] Ibid., 32.

Summary

In the first part of this chapter, the author discussed the role of evaluation in the life cycle of demountable buildings, the evaluation principles and the evaluation process were discussed. It could be argued that evaluation can be seen as a part of the design process, and each design criterion may require knowledge of a specific area. The evaluation principles are discussed by answering four questions:

- What is the evaluation going to be used for?
- Who conducts the evaluation?
- How can the results of the individual evaluation criteria be integrated into a composite measure of criteria?
- What happens after the evaluation?

By examining the generic process of evaluation from pre-occupancy evaluation, to monitoring and post-occupancy evaluation, with a clear concentration on post-occupancy evaluation, it has been shown that the functional performance of a demountable building is best revealed once it has opened to the public.

In the second part of this chapter, a series of existing analysis and evaluation methods that have been successfully used in project assessment and management were presented. General methods, such as Construction Law and Temporary Buildings Design Guide by Aberdeen City Council, are used to analyse qualitative information. In the methods that are used in humanitarian response and cultural development, high-resolution satellite imagery to monitor and evaluate post-disaster recovery is used to collect quantitative data. Post-evaluation of temporary container housing uses both quantitative surveys and qualitative interviews. All other methods, such as UNCHS (Habitat) Guidelines for the Evaluation of Post Disaster Programmes, EMMA and Tearfund Shelter and Reconstructed Standards, are used to collect and analyse qualitative information. In contrast to ISO 14001:2004, which is used for qualitative assessment, all the other environmental assessment methods are used to examine quantitative data, such as distance, sound, thermal and air quality environment. Although CASBEE for Temporary Construction states that it also examines qualitative aspects, such as service performance, functionality, reliability and cultural responsiveness, there is no evidence in the original document that suggests how the evaluation can be carried out. This may be, because the current CASBEE for Temporary Construction only exists in a Japanese version, therefore, it is possible that the Japanese Sustainable Building Consortium and Institute for Building Environment and Energy Conservation are still developing their guidance and evaluation methods for the future.

The evaluation methods for small-scale, public, demountable buildings can be varied and numerous. The preferred choice is often to use existing evaluation tools that have been developed by experts in their respective fields. Each evaluation method may require different information in a particular format, which sometimes makes it difficult to compare the results of one evaluation with another. This can make the use of existing evaluation tools difficult when the results need to be tailored to fit into an integrated system. The selected methods need to reflect the architect or designer's design intentions from a specific perspective.

The lessons learnt are:

(i) Evaluation is often a subjective process, since each evaluator could have different opinions. The results can also differ depending on when evaluation takes place.

(ii) The evaluator should be precise in respect of the stage of evaluation, whether it is pre-occupancy evaluation, monitoring, or post-occupancy evaluation. The indicators differ depending on the evaluation purpose. For example, IES, DesignBuilder, LEED, BREEAM and other computer-based evaluation methods focus on pre-occupancy evaluation, while questionnaires and interview techniques are commonly used during the post-occupancy evaluation process. The methods that claim to be approachable at any stage of an evaluation process, such as ASPIRE, are only appropriate when used for creating uncomplicated reviews and analysis on a holistic scale.

(iii) Quantitative attributes, such as temperature, acoustics and lighting, and qualitative attributes, such as users' opinions of colour, space and appearance, are often evaluated separately. A comprehensive evaluation method should contain both quantitative and qualitative data to holistically address the functional performance of a demountable building holistically. The qualitative data can be quantified by designing a ranking system.

(iv) A ranking system is often used in analysis and evaluation processes to compare the multi-attributes.

(v) A radar chart is often used as a graphical method to display multivariate data, which is often the result of ranking the attributes. Radar charts are a useful way to display multivariate observations with an arbitrary number of variables, although they are not useful when comparing scores. In that instance, a simple chart can be more helpful.

The following table – Analysis and Evaluation Methods Comparison is used as an essential reference for developing the evaluation conceptual model.

TABLE 3.3. Analysis and Evaluation Methods Comparison

Methods	Guidelines Developed by City Council and Cultural Sectors		Assessment Methods in Humanitarian Response							Methods in Environmental Assessment			
	Guidelines by City Council	**Guidance by English Heritage**	**Evaluation of Post Disaster Programmes**	**EMMA**	**Tearfund Standards**	**Surveys and Interviews**	**Toolkit (Save the Children)**	**ASPIRE**	**Satellite Imagery**	**ISO 14001:2004**	**Sensing Systems**	**IES and DesignBuilder**	**CASBEE**
Description	Provides guidance to companies and organisations that need to apply for planning and construction permission for portable buildings, installations or demountable buildings.	Provides guidelines for conservation officers in local planning authorities, owners of heritage sites, event promoters and expert advisers.	Developed by UNCHS, provides a resource to local groups working in post-disaster relief projects to enable them to better monitor and evaluate their programmes for rehabilitation and long-term development.	A set of criteria that can be used as guidance to assist humanitarian staff in emergency situations to better understand and accommodate the market systems of the affected areas.	This shelter and reconstruction standard was developed by Ian Davis, who has over 30 years of experience in disaster relief projects.	Shigeru Ban Architects carried out post-occupancy evaluation through surveys and interviews for their Container Temporary Housing project at Onagawa, Miyagi, Japan.	A practical guide to planning, monitoring, evaluation and impact-assessment by Save the Children UK.	Computer software that carries out the assessment for poverty and informal settlements from four sectors: institutions, environment, economics and society. It costs £250 to purchase online.	A scientifically-based technique to help donors and governments answer key challenges in effectively monitoring and evaluating post-disaster recovery and reconstruction.	An ISO standard aims to identify all potential environmental effects of a company's operations, and to develop and implement a system that limits environmental effects to set targets.	A high-technology method to track small objects through the Global System for Mobile Communications cellular phone technology.	Both are simulation tools that are often used by architects and engineers to assess buildings' environmental performance.	An assessment method for temporary building qualities, including indoor environment, service performance and outdoor environment.
Methodology	Site visits; reporting	Site visits; reporting	Evaluation plan form; develop evaluation indicators, data collection; attributing impact; reporting	Gap analysis; market analysis; response analysis	The main methodology is to summarise the strengths and limitations by reviewing interview records	Surveys; interviews	Surveys; logical framework analysis; cost-effectiveness analysis; using consultants; video	Data collection; data input; present results	Data collection; GIS and imagery analysis; reporting	Surveys; interviews; reporting	Mobile technology; sensing system technology	Simulation; reporting	Data collection; scoring; calculation
Expertise required	Familiarity with the local government policy	Familiarity with heritage protection policy such as historic environment and archaeology	Deep understanding and rich working experience at disaster-affected areas	Deep understanding and rich working experience at disaster-affected areas	Deep understanding and rich working experience at disaster-affected areas	Familiarity with container housing design; knowledge in surveys and interviews	Familiarity with both quantitative and qualitative research strategies	Skills in using ASPIRE software; knowledge of poverty	Advanced understanding in disaster relief projects; good ability in using GIS software	Advanced knowledge of environmental management systems	Strong knowledge and background in computer science, especially GIS-related software	Strong knowledge of building consultancy; ability to use the required software	Strong knowledge and background in numerical assessment; mathematics
Possible evaluator	Architects, designers, environmental consultants, building owners and other enthusiasts	Architects, designers, environmental consultants, archaeologist and other enthusiasts	Policy-makers, architects, engineers, environmental consultants, building owners and other enthusiasts	Policy-makers, architects, engineers, environmental consultants and other enthusiasts	Policy-makers, architects, engineers, environmental consultants and other enthusiasts	Architects, engineers, designers and other enthusiasts	Architects, engineers, designers, environmental consultants, building owners and other enthusiasts	Policy-makers, architects, engineers, environmental consultants and other enthusiasts	Architects, engineers, designers, environmental consultants, building owners and other enthusiasts	Architects, engineers, designers, environmental consultants, building owners and other enthusiasts	Architects, environmental consultants, building owners, researchers and other enthusiasts	Architects, engineers, designers, environmental consultants, building owners and other enthusiasts	Architects, engineers, designers, environmental consultants, building owners and other enthusiasts
Computer platform	Microsoft Office Package	Microsoft Office Package	Microsoft Office Package	Microsoft Office Package	Microsoft Office Package	Microsoft Office Package	Microsoft Office Package	ASPIRE package	GIS; image analysis software	Microsoft Office Package	n/a	IES software; DesignBuilder software	n/a
Strengths	Authoritative	Authoritative; comprehensive; specific	Authoritative; specific	Comprehensive; specific; easy to understand	Authoritative; specific; easy to understand	Specific; easy to understand and use; sufficient	Comprehensive; selective	Comprehensive; visualisation; easy modification	Accurate data; low risk travelling to disaster areas	Specific	Accurate data; no travelling costs and time	Evaluate the design ideas at conceptual stages	Comprehensive
Weaknesses	Lack of further recommendations	Unable to provide consultancy for stakeholders	Difficulties in accessing the affected areas; communication issues	Needs to remain updated in order to solve complicated situations	A lack of more detailed solutions	Time-consuming; travel costs	Not clear in how to adapt tools to a specific project	Not flexible in evaluation indicator modifications	Expensive tools and facilities	Unable to provide consultancy for stakeholders	Expensive tools and facilities; battery waste in tags may damage environment	High costs; software training	Limited to Japanese language; lack of international impacts
Evidence of relevance	For many demountable structures, the first essential step is to obtain permission from authorities such as city councils. It is important for the project owners to be familiar with the up-to-date regulations and public space management policies.	Temporary structures and facilities, such as tents, marquees, seats, stages, television screens, box offices and toilets, are often used at heritage sites for outdoor events. It is essential for the designers to understand how to minimise potential visual intrusion and prevent physical damage through planning and designing temporary structures.	The knowledge of shelter after disaster is extremely important in the demountable buildings because they are commonly used and there have been issues in the past regarding sufficient shelter supplies.	The EMMA toolkit was developed to evaluate disaster relief projects, rather than individual buildings or shelters. However, it can be used as a reference to better understand the refugee crisis and humanitarian issues.	This standard can be adapted by many sectors and used in several situations. However, it is important for agencies that use these guidelines to tailor them to be suitable to their projects. It is also important for international agencies to work closely with the local consultants during disaster recovery projects, from the early planning stage to a later evaluation stage.	This post-occupancy evaluation was organised and conducted directly by the designer. It is not always the high-technology methods that are the most efficient for evaluation. In many cases, especially for post-occupancy evaluation, the most effective method is to communicate with the users through informal interviews and questionnaires.	A collection of analysis methods that can evaluate projects designed to help children in need, which includes both quantitative and qualitative research strategies. The purpose of Toolkit is similar to the author's intention to organise a list of evaluation methods that have potential value for evaluating demountable buildings.	ASPIRE can produce clear evaluation result diagrams that help the users to understand their project from a relatively comprehensive aspect and offer some recommendations. It is still not clear to the users at what point the evaluation should be carried out in order to achieve the most effective results.	This method was used to identify temporary buildings in a range of case studies. A remote sensing system was able to correctly estimate the number of dwellings at the camp site and map the camp's layout.	The Portakabin Group is the first modular building company to commit to meeting the challenges set out in the traditional construction industry. It has gained recognition for high standards of environmental management and commitment to ongoing environmental responsibility with accreditation to the ISO 14001 International Standard.	This sensing system could be used to trace each building or structural component. As a result, the path and time of "travelling" would be clearly identified through monitoring the tracks on the computer. This will help analyse the construction, exhibition and deployment process.	Both IES and DesignBuilder are computer software packages that can be utilised by building consultants for energy analysis and to obtain accurate environmental performance data. They can be used for all types of construction, including demountable building designs.	CASBEE for Temporary Construction has been successfully applied to two large-scale, demountable buildings: The Japan Pavilion Nagakute and the Japan Pavilion Seto, both exhibited during the Expo 2005 in Archi Japan.

3.6 A Conceptual Model for Evaluation

Having identified the key factors of demountable buildings and studied the existing evaluation methods, the results of the review suggest that a conceptual toolkit can be proposed to develop a conceptual model for the effective evaluation and evidencing the value of demountable buildings. In order to achieve this, two main criteria must be met:

- This method will be developed for building users and visitors, and practitioners engaged in the commissioning, design, planning, production and management of the demountable building.

- This method will focus specifically on assessing and measuring the functional value of the completed demountable building, and will provide a unique tool for everyone involved in the production and use of buildings to gain a deeper understanding of their design.

Through a review of the relevant literature, the Design Quality Indicator (DQI) method, which "seeks to complement methods for measuring performance in construction by providing feedback and capturing perceptions of design quality embodied in buildings",[150] was identified. The key features of the DQI include:

- It is a pioneering process for evaluating the design quality of buildings. The DQI is based on a research project aiming to provide a toolkit for improving the design of buildings. It seeks to complement methods for measuring performance in construction by providing feedback and capturing percentages of design quality embodied in buildings. Development of the DQI has been led by the CIC (Construction Industry Council), with sponsorship from the DTI (Department of Trade and Industry), CABE (Commission for Architecture and Built Environment), Constructing Excellence and Strategic Forum for Construction, and with support from the OGC (Office of Government Commerce). The DQI can be developed into an easy-to-use online tool, with access for everyone involved in the procurement and use of buildings.

- David M. Gann, Ammon J. Salter and Jennifer K. Whyte argue that the benefit of the DQI is its role as a "tool for thinking", rather than being an

[150] David M. Gann, Ammon J. Salter & Jennifer K. Whyte David M. Gann, "Design Quality Indicator as A Tool for Thinking," *Building Research & Information* 31, no. 5 (2003): 318.

absolute measure. As such, it has the potential to capture lessons from current building designs for strategic future use, as well as initiate, represent and inform discussion involving designers, clients, producers and end-users and their perceptions of the tangible and intangible aspects of the possibilities within live design projects.[151] The benefits of the DQI make it suitable for developing a conceptual evaluation model for demountable buildings because, as outlined in Chapter 2, the evaluation methods can be varied and optional, and the key is to select methods that reflect the architects' design intentions.

The key features of the DQI satisfy the required criteria for developing a conceptual model, therefore suggesting that the DQI is suitable for being adapted for the design of a new tool that can be used for the post-occupancy evaluation of small-scale, public, demountable buildings.

In order to clarify the scope of the evaluation model, the term *conceptual model* has the following meanings:

- It is not intended for a direct application in the building assessment industry or market. Although this thesis concludes that there are the possibilities for developing the conceptual model further into a direct practical toolkit.

- It intends to convey a common conceptualisation through which it is possible to develop an understandable evaluation model. The model is adaptable for its broadest users, including architects, designers, clients, building users and all other stakeholders.

- As a conceptual model, it does not cover a wide range of evaluation factors. Instead, it concentrates on solving the specific problem of how to evaluate the functional performance of small-scale, public, demountable buildings.

Twenty-seven indicators are identified through the previous research: thermal comfort quality, acoustic quality, spatial comfort quality, design for disabled users, circulation space, furniture arrangement, storage consideration, usability, maintainability (material), maintainability (structure), construction preparation, physical plant, administrative service cost, cost of allocation, dismantling cost, cost for transportation and storage, usage time, deployment time, transportation time, scale, structure, material, colour, illumination (daylight), illumination (artificial

[151] Ibid.

lighting), acceptability to the users and appropriateness at the building site. They were selected following these instructions:

- Evaluation indicators are reasonable and appropriate, which means that they present the key features of demountable buildings, and they are concerned with the building's functional performance but no other performance, including energy costs and temperature measurement. They are also related to post-occupancy evaluation.

- The evaluation questions regarding the indicators are measurable and answerable. They should be able to identify clear and observable dimensions of functional performance that are relevant to the evaluation goal and represent domains in which the evaluation can realistically be expected to make accomplishments. The evaluator can select a single answer from five options: *strongly disagree*; *disagree*; *neither agree nor disagree*; *agree* and *strongly agree*.

The FFTA Tool

The FFTA (function-finance-timescale-aesthetics) tool assists a demountable building's management team in defining and checking the evolution of functional performance quality at the post-occupancy evaluation stage. There are two main parts to the FFTA tool: the FFTA questionnaire and the FFTA visualisation. The FFTA questionnaire is a coherent, straightforward, non-technical set of statements that collect the opinions from all stakeholders by looking at the function, finance, timescale and aesthetics of small-scale, public demountable buildings. *Function* concerns a demountable building being used effectively for what it is intended. This is split into use, access, space and usability. *Finance* focuses on reviewing the final costs of the building and the consideration of dismantling costs, waste management, transportation and storage, where applicable. *Timescale* relates to examining the use-time of a building, and the time for building deployment and transportation after dismantling. *Aesthetics* is assessed from the visual appearance of the building, as well as acceptability to users and appropriateness at the building sites.

The FFTA questionnaire includes two sheets: the evaluation indicator list, and the details of the questionnaire. The purpose of the indicator list is to clarify the exact meaning of each indicator and provide a common understanding for the evaluator before they fill in the questionnaire. The questionnaire is presented on a single sheet, with clear instructions that allows the evaluators to treat uncertainty explicitly, thus, when the evaluator is asked about their opinion on the colour of the building, they are able to select a response from five alternatives in hierarchy order from low to high: *strongly disagree*, *disagree*, *neither agree nor disagree*, *agree* and *strongly agree*.

TABLE 3.4. Explanation of the evaluation indicators

	Indicators		Description
Function	01	Thermal comfort quality	Many small-scale public demountable building are constructed from materials that are not commonly used, such as paper tubes, cardboard and natural fabrics. This indicator evaluates whether “unusual” materials offer good thermal comfort to the building users.
	02	Acoustic quality	Evaluates whether the building/structure offers good acoustic quality to the building users.
	03	Spatial comfort quality	Evaluates whether small-scale projects offer good spatial comfort quality to the building users.
	04	The design for disabled users	Evaluates whether the design for disabled users was well planned.
	05	Circulation space	Evaluates whether the circulation space was well designed.
	06	Furniture arrangement	Evaluates whether the furniture can be well arranged within a limited area.
	07	Storage consideration	Describes whether small-scale projects offer good storage space considerations for the users.
	08	Usability	Evaluates the usability of the building/structure to the users (promoters/clients and the end-users), including how convenient it is for the clients to host activities inside the building and how easy it is for the building users to participate in these activities.
	09	Maintainability	Evaluates the efficiency of the building; this can be affected by factors such as weather, temperature, quality of the building and the construction skill levels.
Finance	10	Construction preparation	Evaluates the final construction preparation cost against the planned cost (construction materials, building machinery and tools).
	11	Physical plant	Evaluates the final physical plant cost against the planned cost (hiring construction workers, design service, operation and transportation of building elements or components).
	12	Administrative service cost	Evaluates the actual administrative service costs against the planned cost.
	13	Waste management	Evaluates the cost of disposing of waste building/structure materials.
	14	Dismantling cost	Evaluates the cost for dismantling against the planned cost.
	15	The cost of transportation and storage	Evaluates the cost for transportation and storage after the building/structure is dismantled either for re-deployment or recycling.
Timescale	16	Operation time	Evaluates the actual operation time of the building/structure against the planned time.
	17	Deployment time	Evaluates the actual deployment time of the building/structure against the planned deployment time.
	18	Dismantling time	Evaluates the actual dismantling time of the building/structure against the planned time.
	19	Transportation time	Evaluates the actual transportation time of the dismantled building/structure for either re-deployment or recycling against the planned time.
Aesthetics	20	Scale	Evaluates whether the scale of the building/structure is suitable to the users and building site.
	21	Structure	Evaluates the efficiency of the structure, including its appropriateness to the material used and its appearance.
	22	Material	Evaluates the selection of materials, including their suitability to its appearance and convenience for the construction.
	23	Colour of the building/structure	Evaluates the appearance of the building/structure from both internal and external views.
	24	Illumination (daylight)	Evaluates whether the combination of colour and light without artificial lighting can function well for the building users.
	25	Illumination (artificial lighting)	Evaluates whether the artificial lighting can function well for the building users.

	26	Acceptability to the users	Evaluates the acceptability of the building/structure to the users, measuring how well the design is accepted by people psychologically.
	27	Appropriateness of the building site	Evaluates the appropriateness of the building/structure at the construction site, including the arrangement, positioning of the building and the access links to the building.

TABLE 3.5. Details of the questionnaire

Design Quality Indicators of Small-Scale Public Demountable Buildings (Post-Occupancy Evaluation)						
Instructions	The Conceptual Evaluation Model was developed by Junjie Xi as a part of the research results in the evaluation of small-scale public demountable buildings. There are 27 indicators in the model. Please select the checkbox that you feel is most suitable for your design. Please only select one option for each indicator	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
	Performance Indicators	**1**	**2**	**3**	**4**	**5**
Function	1. The thermal comfort quality (temperature and humidity) is appropriate for its use.	☐	☐	☐	☐	☐
	2. The acoustic quality is appropriate for its use.	☐	☐	☐	☐	☐
	3. The spatial comfort quality is appropriate for its use.	☐	☐	☐	☐	☐
	4. The design for disabled users is well planned.	☐	☐	☐	☐	☐
	5. There is circulation space left for the emergency exit.	☐	☐	☐	☐	☐
	6. The furniture can be well arranged inside the building.	☐	☐	☐	☐	☐
	7. The storage is well considered.	☐	☐	☐	☐	☐
	8. It is convenient for the promoters/clients to use the building/structure.	☐	☐	☐	☐	☐
	9. The building/structure will weather well and can be easily maintained.	☐	☐	☐	☐	☐
Finance	10. The final cost of the construction materials, building machinery and tools is appropriate for the budget.	☐	☐	☐	☐	☐
	11. The final cost of the physical plant is appropriate.	☐	☐	☐	☐	☐
	12. The final cost of administrative services is appropriate.	☐	☐	☐	☐	☐
	13. The final cost of disposing of waste building/structure materials is appropriate.	☐	☐	☐	☐	☐
	14. The final cost of dismantling is/will be appropriate.	☐	☐	☐	☐	☐
	15. The final cost of transportation after dismantling will be appropriate.	☐	☐	☐	☐	☐
Timescale	16. The use-time of the building/structure is the same as planned in the design brief.	☐	☐	☐	☐	☐
	17. The time for deployment is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
	18. The time for dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
	19. The time for transportation after dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
Aesthetics	20. The scale of the building/structure is aesthetically appropriate.	☐	☐	☐	☐	☐
	21. The building's structure is aesthetically suitable.	☐	☐	☐	☐	☐
	22. The selection of the construction material is appropriate.	☐	☐	☐	☐	☐
	23. The colour of the building/structure is appropriate and appreciated by its users.	☐	☐	☐	☐	☐
	24. There is adequate daylight in the building.	☐	☐	☐	☐	☐
	25. The artificial lighting levels in the building/structure are satisfactory.	☐	☐	☐	☐	☐
	26. The building/structure produces a low number of complaints/faults reported by users.	☐	☐	☐	☐	☐
	27. The owner of the site is pleased with the building/structure.	☐	☐	☐	☐	☐

The weighting system of FFTA can be applied and indicates the evaluator's opinion: *strongly disagree*, *disagree*, *neither agree nor disagree*, *agree* and *strongly agree*. The results can be distorted depending on how the respondents judge the success of various aspects of the building.

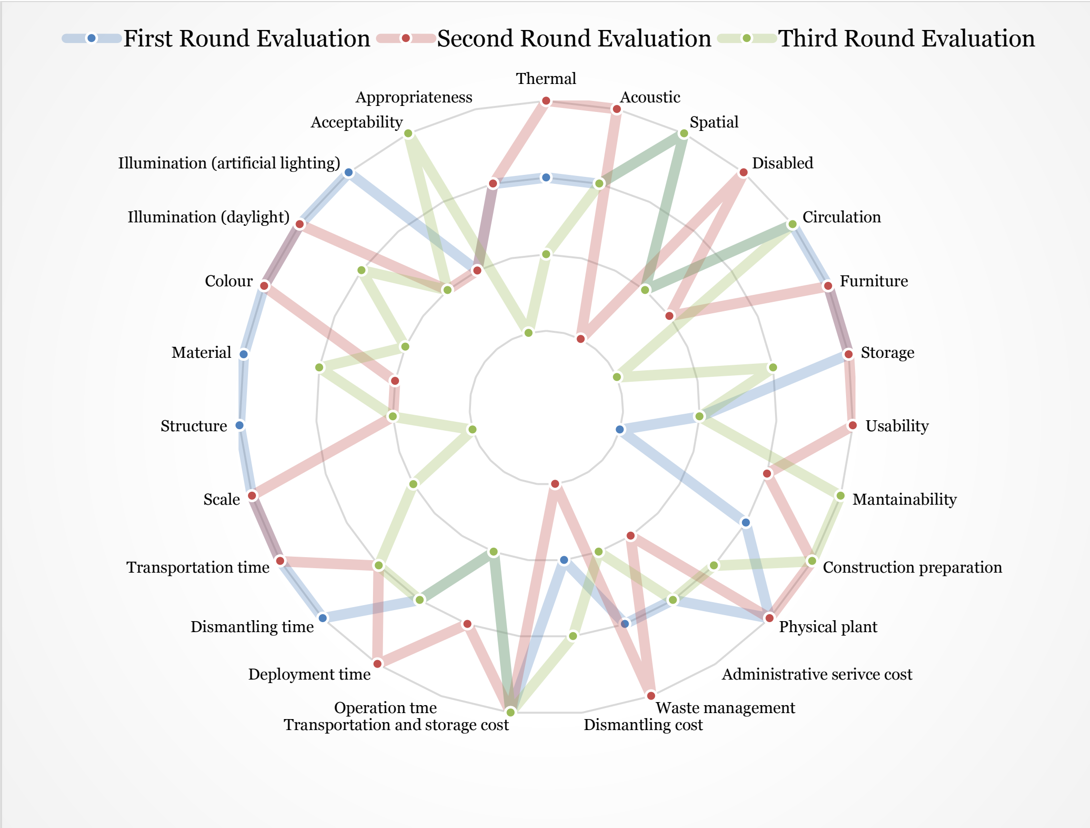

FIGURE 3. 23. The FFTA weighting diagram – a possibility

FFTA can be graphically presented in various ways and can highlight comparisons between groups of respondents, comparing the views of the building's eventual users with those of the delivery team. For example, each stakeholder can rank the indicators separately, and the results can be generated together for further comparison. It can also be used to compare a number of stages of the evaluation and present how these are being achieved by the modifications in design. For example, after a demountable building is evaluated and dismantled for further use, design changes are sometimes made because of common factors such as the clients' needs, site requirements or a part of the building components needs to be replaced. When the building is used for the second or third time, the evaluation results can be different. At this stage, the results can be presented for comparison and reviewing over time.

The FFTA conceptual tool has been developed for the post-occupancy evaluation of small-scale, public use, demountable buildings. It can be used by architects, designers, project owners, other stakeholders or external evaluators who are interested in examining the functional performance of the projects.

It can be used flexibly according to the evaluator's requirements. For example, based on the same criteria, the architect can first rank each indicator, and later use the results of questionnaires and interviews with users to rank the indicators for a second time from the users' perspective. Therefore, two results can be presented together for comparison and, by doing this, the differences can be easily identified for further investigation.

Having proposed an evaluation conceptual model, the next step is to identify a series of case studies and test the usability and practicability of this model through projects that have been successfully constructed and used to serve their functions.

4

Case Studies

4.1 Introduction

Three case studies have been selected for consideration in this research: Chengdu Hualin Elementary School in Chengdu, China, designed by Shigeru Ban Architects from Japan, 2008; Exxopolis, designed and exhibited in 2012 by Architects of Air, a company based in Nottingham, UK, with twenty years of experience in designing and constructing inflatable structures; and Kreod, a multi-functional structure delivered by designer Chunqing Li, exhibited from 18 September 2012 – April 2013 between the O2 Arena and Emirates Air-Line in the Greenwich Peninsula, London, with plants for further display in the UK after dismantling.

FIGURE 4. 1. - FIGURE 4. 3. Chengdu Hualin Elementary School; A choir performance inside Exxopolis; Kreod in the evening

These case studies have been used as part of a research strategy to collect evidence and test the hypothesis, and they have been selected due to:

- their approachability, in that the author could access and interview the designers, and received a positive response regarding the research. This was a fundamental requirement for carrying out research in these case studies because data could not be assessed and collected without full co-operation from designers and project owners.

- their appropriateness to the research topic. All of the three case studies are entirely demountable structures and designed for public use. In Chapter 2, *public building* was defined as having two meanings: buildings for the general public; and buildings for a group of people with shared interests or activities. The Hualin School is specifically used by pupils aged between 7 and 12 and by school teachers. The Exxopolis project is designed for the general public, including disabled people and people with special requirements. The Kreod project can be used exclusively for private events hosted by the sponsors of this project. It is also open to the general public during the daytime and closes at night-time, unless there is an evening event.

- they were built before the completion of this research. The Hualin School was built in September 2008 and it had been in use for two years when the author first identified it as a key case study. The Exxopolis project is the first design from Architects of Air to be completed mainly through computer software (Rhino 3D). It was first opened to the public in June 2012 and is currently scheduled to tour Austin and Houston, Texas and Cleveland, Ohio, both in the US. Finally, designer Chunqing Li started the design for Kreod in 2009 under the name *Pavilion Architecture*. For many reasons, such as funding and structural tests, it was not ready to be built in 2010 as planned but after graduating with a BA (Hons) in architecture from Liverpool John Moores University, Li continued working on his design and obtained sponsors including RIBA (Royal Institute of British Architects), Sheetfabs,[1] and the China International Art Foundation[2]. Kreod was launched in September 2012 and is, at the time of writing, still on display.

- investigating the principles of a series of case studies increases the research quality substantially by providing a chain of evidence that links the questions asked with the data collected, and allows conclusions to be drawn. It should be noted that the case studies are used to provide a generic understanding that concentrates on the evaluation of demountable buildings whilst not specifically focusing on distinguishing the functional performance of school buildings or exhibition buildings.

[1] Sheetfabs is a company based in Nottingham that specialises in the manufacturing and installation of all scales of projects, using mild steel, stainless steel and aluminium.
[2] CIAF (China International Art Foundation) is a company registered in the UK that aims to promote trading between China and the UK.

Four themes were examined in each case study: function, finance, timescale and aesthetics. Each was presented as a report with a post-occupancy evaluation sheet attached. The findings of each report, ascertained through site visits, questionnaires and interviews with designers and building/structure users, were analysed with the conclusions presented below.

4.2 Chengdu Hualin Elementary School

An earthquake with a magnitude of 8.0 struck in Wenchuan, China on 12 May 2008, killing 69,000 people and leaving 4.8 million homeless. Shortly after the earthquake, Japanese architect Shigeru Ban arrived in Wenchuan with architect Hironori Matsubara and a building consultant from Beijing, to propose a temporary residence design to the local government. The laboratories from Japan and professors from the Faculty of Architecture in Southwest Jiaotong University quickly came to an agreement and started to work together on the design. They first assembled a full-size model of the dwelling on the campus of Southwest Jiaotong University and took their proposal to the local government. However, due to a lack of experience in China of using paper as a building material, the proposal was not approved. Furthermore, according to Hong Yin[3], the local government did not plan to construct much transitional housing as their main recovery solution was to build new permanent buildings quickly.[4]

FIGURE 4. 4. - FIGURE 4. 5. A full size model of a residence dwelling in the campus of Southwest Jiaotong University (during construction); Completed model

[3] Hong Yin is a lecturer at the School of Architecture, Southwest Jiaotong University. She was one of the volunteer organisers of the Chinese students and teachers for the Hualin School project.
[4] Hong Yin, in discussion with the author, November 2011.

Instead, it was suggested by a local NGO (Non-governmental Organisation), Shenzhen Re-Tumu Professional Volunteer Group, that the idea should be applied to building temporary classrooms for the Hualin Elementary School, where two of the three school buildings were badly damaged during the earthquake and condemned as unsafe for habitation.[5] Once approval came from education officials, a team was set up including students from Ban's laboratory in Japan, the Hironori Matsubara Lab at Keio University Shonan Fujisawa Campus, and volunteer teachers and students from around China. The aim was to erect temporary but resilient school buildings out of plywood and recycled cardboard tubes before the new term started in September. Ban had vast experience of working with recycled paper, and he had used paper tubes in the past to construct shelters following earthquakes in India, Turkey, Japan and Sri Lanka. One of the chief strengths of Ban's design is that it employs relatively inexpensive and widely available materials to achieve a structurally sound proposal.

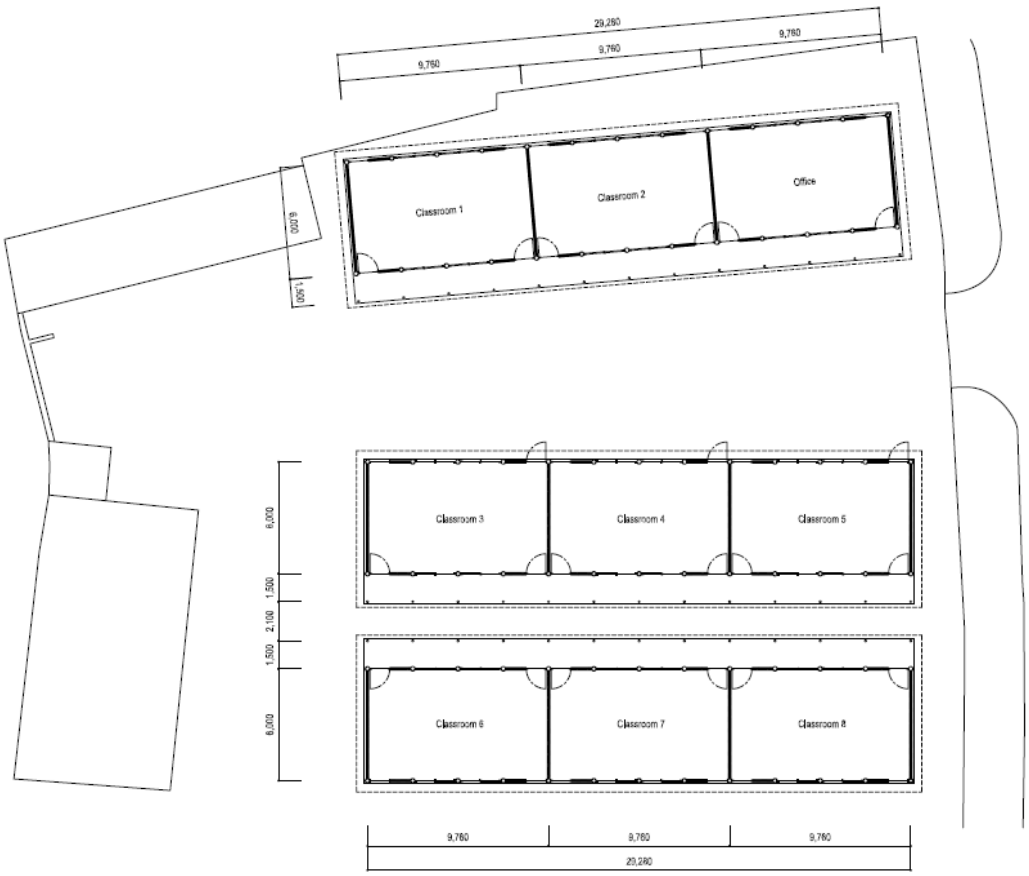

FIGURE 4. 6. Chengdu Hualin Elementary School site plan[6]

[5] Ban et al., *Shigeru Ban : Paper in Architecture*: 148.
[6] Yasunori Harano, Email, 2010.

The key references in this case study include *Voluntary Architects' Network* by Shigeru Ban and Keio University SFC Ban Laboratory, *Shigeru Ban: Paper in Architecture* by Shigeru Ban, Riichi Miyake, Ian Luna and Lauren A Gould, and *Shigeru Ban: Complete Works: 1985 - 2010* by Shigeru Ban and Philip Jodidio. Formally interviews were also conducted with a group of professionals who were involved in the project. They included: Japanese architect Yasunori Harano, who was also the volunteer organiser of the Japanese students; Hong Yin and Jing Deng who were volunteer organisers of the Chinese students and teachers, and the former guided the construction workers during the building repair work in 2011 after a request from the Hualin Elementary School; Lin Hou, a postgraduate architecture student from Southwest Jiaotong University who participated as a volunteer student leader and later completed his Master's thesis on a temporary building design topic; Xiaodu Liu[7], who is one of the Principals of architecture company Urbanus,[8] China, and director of Shenzhen Re-Tumu Professional Volunteer Group; Mr Li, director of the Hualin Elementary School; and Reiji Watabe, one of the volunteer students and now a member of staff at Shigeru Ban Architects Company, Japan. In addition to recorded formal interviews, conversation-led informal interviews were used to obtain feedback from school teachers and students. The use of questionnaires was essential in collecting qualitative and quantitative data from building users and volunteer students. The designer was consulted prior to planning the questionnaires in order to obtain the optimum information from this case study. In an email to the author on 22 October 2010, Harano wrote:

> I think it is better to prepare two questionnaires: 1 volunteer workers including Chinese teachers, Chinese students, and Japanese students. 2: users (pupils in school). It is clearer and you can survey about the volunteer work in 1 and the living environment in 2. And what is important in the survey is to get a permission from the university, education bureau and Hualin School. I think Mr Deng Jing will help you with your research but it is important to consider this kind of permission issue.[9]

After careful consideration and further discussion with Harano, three questionnaires were designed. An online questionnaire was first prepared and sent to volunteer students, to assess whether the project helped the architecture students to improve

[7] Xiaodu Liu is one of the founding partners of Urbanus and he was awarded his Bachelor of Architecture from Tsinghua University in Beijing, China and Master of Architecture from Miami University. The author arranged to meet him in London when he came to deliver a lecture at the Royal Academy of Arts on 26 April 2012. His talk was recorded and it is accessable online through: http://www.royalacademy.org.uk/events/talks/urbanus-and-its-critical-urban-practice,1964,EV.html.
[8] Urbanus is an architectural practice in China, founded in 1999 by Xiaodu Liu, Yan Meng and Hui Wang. Their work was presented as a part of an exhibition at the Building Centre in London that offered an insight into the work of a new generation of contemporary Chinese Architects.
[9] Yasunori Harano.

their construction skills. Following a visit to the school in November 2010, and 373 valid questionnaires were obtained from school pupils and 20 questionnaires from the teachers. At the time of the field research, the pupils studying in the paper school were from Grade One, Two and Four (age 7 to 10). Pupils from Grade Six (aged 12) studied in the paper classrooms from 2008–2009, but were relocated to the concrete building in 2010. The questionnaires were handed out by the teachers to those pupils in Grade Two, Four and Six who had experience of studying in the paper classrooms. No questionnaires were given to pupils from Grade One even though they were also studying in the paper school, because of their writing skills at a young age. Questionnaires were not given to students from Grade Three or Five because they only had experience of studying in the concrete building.[10]

TABLE 4.1. Chengdu Hualin Elementary School case study research methods

Case Study Research Methods							
Literature	**Interviews**				**Questionnaire**		
Voluntary Architects' Network; *Shigeru Ban: Paper in Architecture*; *Shigeru Ban: Complete Work: 1985–2010*	***Name***	***Role***	***Method***	***Date***	***Group***	***No.***	***Date***
	Yasunori Harano[11]	Designer and volunteer organiser (Japanese side)	Skype	11/09/2010 20/11/2010	Pupils	373	23/11/2010
	Jing Deng	Volunteer organiser (Chinese side)	Phone	15/10/2010	Hualin school teachers	20	23/11/2010
	Lin Hou	Volunteer students team leader (Chinese side)	In-person (Chengdu, China)	23/11/2010	Volunteer students	7	11/2010
	Hong Yin	Volunteer organiser (Chinese side)	In-person (Chengdu, China)	26/11/2010	Designer	1	12/2012
	Mr Li	School leader	In-person (Chengdu, China)	23/11/2010			
	Xiaodu Liu	The head of the NGO Rebirth of Environment	In-person (London, UK)	27/04/2012			
	Reiji Watabe[12]	Volunteer	Skype	04/12/2012			

[10] Li, in discussion with the author, November 2011.
[11] Yasunori Harano was born in 1977 and works for Shigeru Ban Architects, primarily in Tokyo, and sometimes in other countries when required. He worked in Sri Lanka from 2005 after the company proposed the reconstruction of the mosque in Sri Lanka that was destroyed by the tsunami after the earthquake in the same year.
[12] Reiji Watabe was born in 1986 and works at Shigeru Ban Architects Tokyo office in Japan. He was an architecture student at Keio University in 2008 when he participated in the Hualin project. He was the only one of the Japanese volunteers who visited the school in 2009, after the completion of the paper school.

4.2.1 Function

The original function of this project was to temporarily provide a pleasant teaching and studying environment for school teachers and students. Nine classrooms, 9.7m long, 6m wide and 4.68m in height, were designed. With seven of them used as classrooms, one used as an office, and one as a computer room for IT lessons. Each of the classrooms is equipped with one television, four electric wall fans, 12 fluorescent lights on the ceiling and 3 in front of the class above the blackboard. The office and the computer room are equipped with computers, fluorescent lights and air conditioning units. The major activity inside the buildings is teaching although the pupils tidy and clean the classrooms every day after school before they leave for home. The author assessed the function of the building with regards to the quality of thermal comfort acoustics and spatial comfort, through interviews and questionnaires.

FIGURE 4. 7. - FIGURE 4. 9. Inside view of a classroom; Inside view of an office; Electronic wall fan

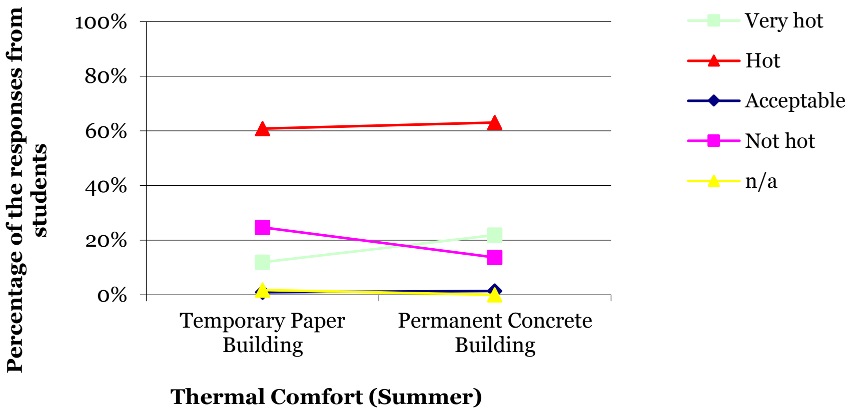

FIGURE 4. 10. Thermal comfort (summer)

According to the results of the informal interviews with the participating school teachers, the temperature inside the temporary classrooms in summer is 4–5 degrees higher than those in the concrete school buildings (Figure 4.10.). However, the results from the questionnaires sent to pupils suggested that the temperatures in summer in the paper classrooms and in the concrete classrooms are similar, or that it is slightly cooler in the paper classrooms (all classrooms have the same cooling facilities with four walls fans in each classroom).

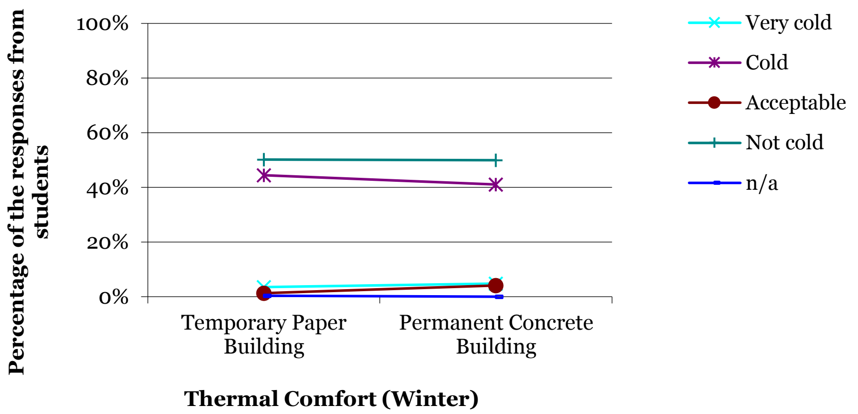

FIGURE 4. 11. Thermal comfort (winter)

Questionnaire results also indicate that, in winter, the temperatures in the paper classrooms and in the concrete classrooms are similar, and over half of the students think it is not too cold to study in either the paper classrooms or the concrete classrooms (Figure 4.11.). Most schools and universities in China have no heating systems in the buildings, and, therefore, students and teachers protect themselves against cold by wearing thick winter clothing to keep warm.

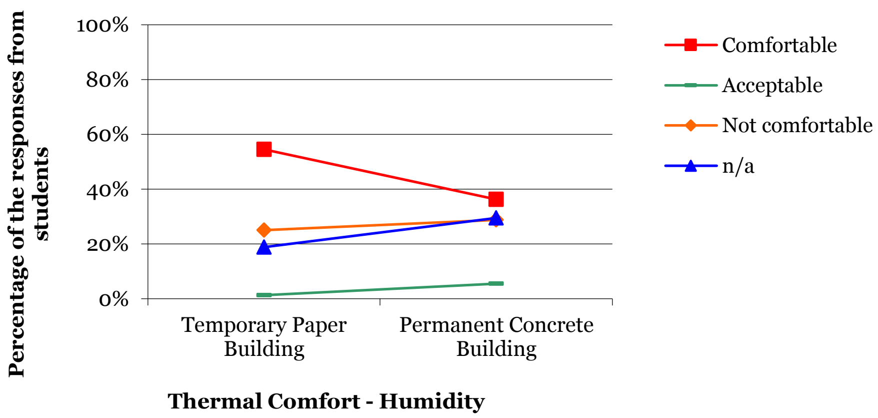

FIGURE 4. 12. Thermal comfort - humidity

In terms of humidity, the majority of the students who studied in the paper building felt comfortable during rainy days. Overall, the percentage of the students' opinions regarding comfort in the temporary paper building was 18.3% higher than their opinions of comfort in the permanent concrete building (Figure 4.12.). The results from the questionnaires indicate that the paper classrooms provide a similar quality as the permanent school in respect of providing a relatively pleasant thermal environment.

FIGURE 4. 13 - FIGURE 4. 14. The School is built next to a main road; A playground is located between the *paper building* and the concrete building

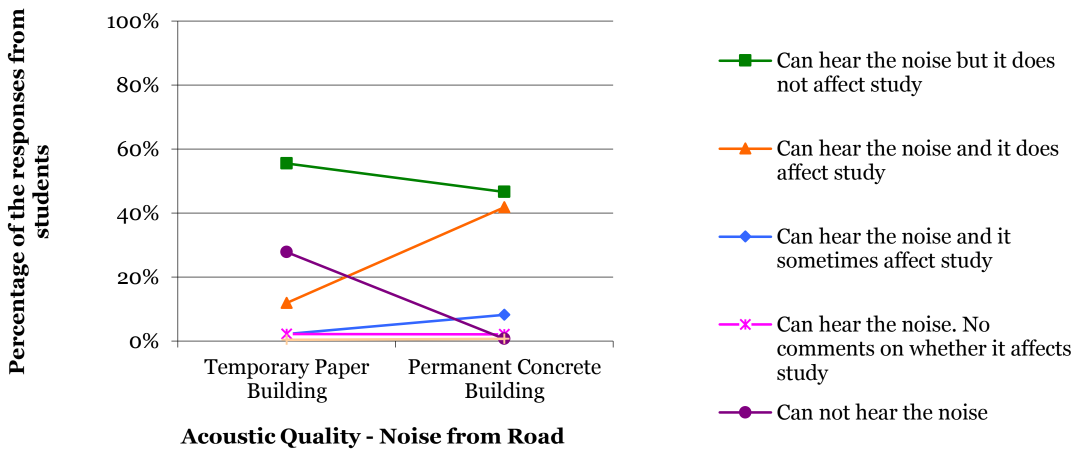

FIGURE 4. 15. Acoustic quality – noise from road

Regarding the acoustic quality, three indicators were examined including the effects of the noise from the road, from other classrooms and from the playground. The results of the questionnaires indicate that more pupils who were studying inside the paper building could hear the noise from the road, but that this did not affect their study (Figure 4.15.). Another interesting issue rises from this question, however, which suggests that more students who were using the concrete building were affected by the traffic noise from the road. However, this result does not indicate that the sound-proofing in the paper school is better than in the concrete school, because there are other reasons that could have caused this result, such as the distance between the concrete building and the road is around 10m shorter than the distance from the paper building to the road.

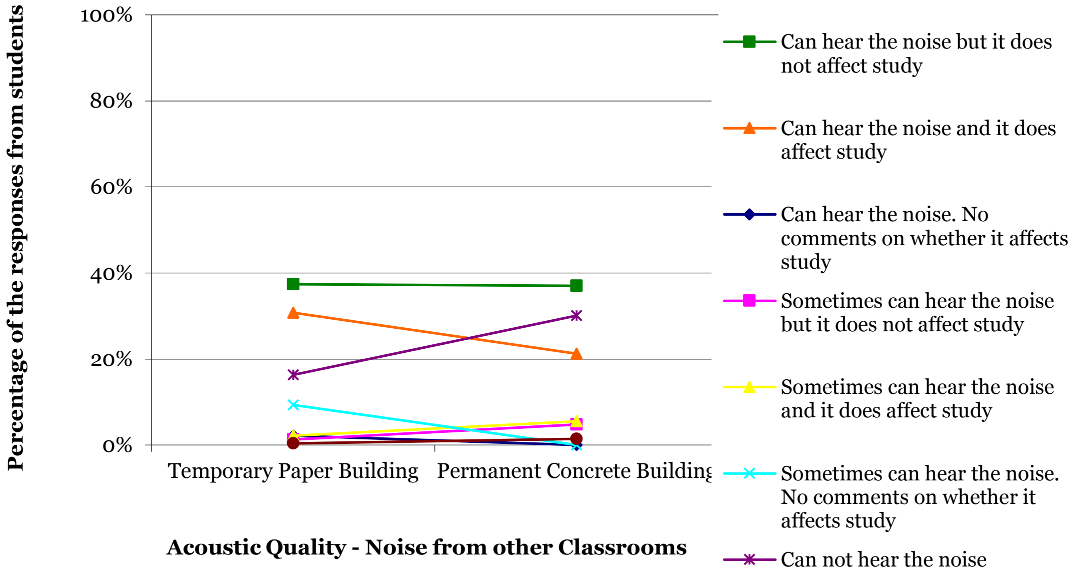

FIGURE 4. 16. Acoustic quality – noise from other classrooms

The results of the questionnaire shows that more pupils in the paper school were affected by the noise from other classrooms, although many factors may have caused this result, including the fact that students in Grade One, Two and Four who were studying in the paper building were younger and, therefore, more active (Figure 4.16.). The pupils in Grade Six who participated in the questionnaires were facing exams to go to secondary school and had less musical classes due to examination preparation.[13]

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[13] Teacher, in discussion with the author, November 2010.

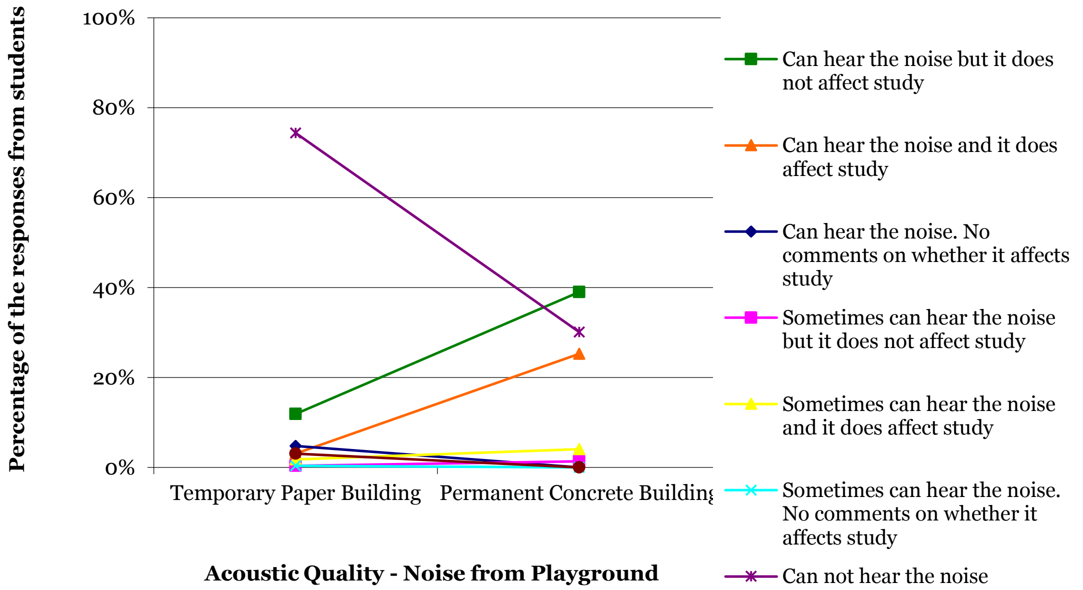


FIGURE 4. 17. Acoustic quality – noise from playground

Finally, a playground is located between the paper building and the concrete building where pupils take P.E. classes and spend time during their class breaks. During school time, whilst some classes take place indoors, others have P.E. classes on the playground. The results from the questionna demonstrate a satisfactory result, where more pupils studying in the paper school could not hear the noise from playground, and they were less affected by it (Figure 4.17.). However, the results do not indicate that the sound-proofing in the paper school was better than in the concrete school because there are other factors that could have caused this result, such as the physical distance from the playground.

FIGURE 4. 18. - FIGURE 4. 19. Students in a classroom during a class break; A small corridor space between the two terraced classrooms

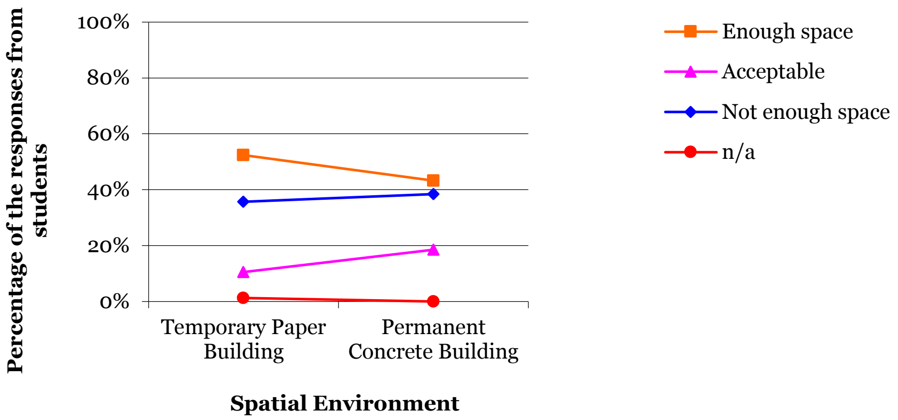


FIGURE 4. 20. Spatial environment

Regarding the quality of spatial comfort, each classroom is 9.76m × 6m × 4.68m, and has a capacity for 30–35 pupils. The results of the questionnaires demonstrate that more pupils inside the paper building felt there was abundant space (Figure 4.20). This may be two reasons for this. Firstly, there are windows on both sides of the paper classrooms, while only one side of the classrooms in the concrete buildings have windows. More natural light could lead to a feeling of more space. Secondly, the roof design in the paper classroom is pitched, which creates more space than the flat roof used in the concrete building design. As previously mentioned, there is a small corridor between the two terraced classrooms, 5.1m in width and 29.28m in length and the generous scale of the corridor was appreciated by the pupils, and has become a popular space during breaks. On this compact site, spatial design has a particular potency in a location that all users of the building are able to enjoy.

FIGURE 4. 21. The fluorescent lights on the ceiling in one classroom

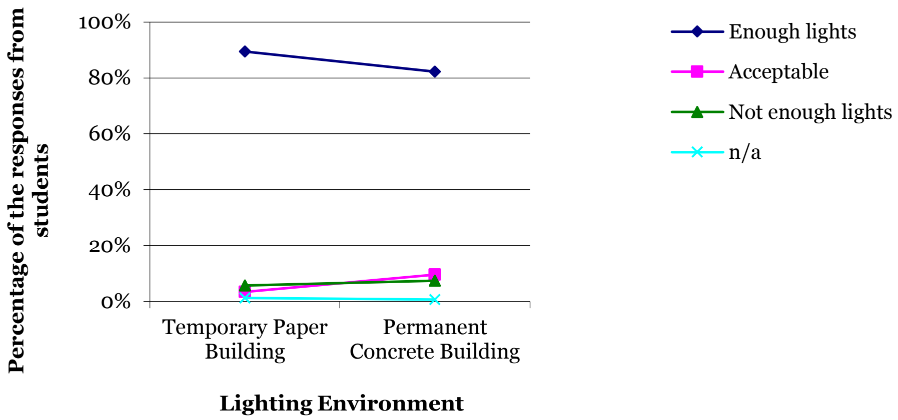


FIGURE 4. 22. Lighting enviroment

Regarding the lighting system in the building, the results of question number 5 suggest that slightly more pupils who were studying in the paper building felt there was adequate light inside the classroom (Figure 4.22.). This result matches Ban's explanation that he uses large holes on the roof design of buildings to generously illuminate the interior. [14] Steane argues that classroom lighting is a major consideration in school design across all countries. She states that the kind of the environment a classroom should provide has changed over the last 150 years in accordance with views on how children should be taught.[15]

The above discussion shows that a demountable building can provide the same functional performance as a permanent building. Although researchers and designers might argue that the paper tubes are industrial products rather than mass-produced material for buildings, the unusual material used in this case has been proven to be a durable and reliable construction material.

4.2.2 Finance

The funding bodies of the Paper School were Chengdu Education Bureau alongside donations from bodies such as Rebirth of Environment, which donated 100,000 RMB (£10,000).[16] The project budget was 580,000 RMB (£55,680); although the actual cost was around 680,000RMB[17] (£65,280).[18] All the construction materials,

[14] Ban et al., *Shigeru Ban : Paper in Architecture*: 148.
[15] Steane, *The Architecture of Light : Recent Approaches to Designing with Natural Light*: 161.
[16] Xiaodu Liu, in discussion with the author, April 2012.
[17] Jing Deng, in discussion with the author, October 2010.

including paper tubes, plywood, timber joints, nails, PVC windows and doors, were purchased in China and mostly in the local area. Part of the paper tubes were manufactured in Guangdong southern China, because they had better techniques in making the paper that was required. The majority of the construction machinery, such as cutting machines and other construction tools, was borrowed from the Architecture School at Southwest Jiaotong University.

FIGURE 4. 23. A classroom in the concrete building was used as a workshop to store materials and construct small joints[19]

The building was constructed completely by volunteers. No design service fee was charged and the Hualin School offered basic on-site accommodation and food for the volunteer students. The total number of volunteers was 127, of which 94 were Chinese students, teachers at Hualin School and the Chengdu Bureau of Education, and local carpenter, Chengjun Zhou; 25 were Japanese students; and eight, including Shigeru Ban and Matsubara Hironori were from various organisations. Zhou played an important role in this project with his expertise and skills in working with wood and timber as construction materials and as Watabe describes, "We would not have been able to do this without him."[20] Hou states that Zhou's role was much more than that of a carpenter, because his job also included monitoring the construction process and directing the volunteers on site.[21]

[18] The budget in GBP was calculated by the author, according to the exchange rate of GBP 10.63 on 15 February 2011. This information is available on http://www.boc.cn/sourcedb/whpj/enindex.html.
[19] Akihiko Tanigaito, "Chengdu Hualin Elementary School," (2008).
[20] Reiji Watabe, in discussion with the author, December 2012.
[21] Lin Hou, in discussion with the author, November 2011.

FIGURE 4. 24. - FIGURE 4. 25. A photo of some of the volunteers**;** A classroom was used as temporary accommodation for the volunteers[22]

Most of the leftover materials were made into chairs and bins, designed by architect Hironori Matsubara and Yasunori Harano. This approach not only reduced the material waste, but also encouraged the pupils to be a part of the team. All the paper tube bins were decorated by the pupils and treated with waterproof paint. However, some discussions between the architects and volunteers were not clear enough and, thus, incurred extra costs. For example, some plans and specifications were sent by email without being discussed in face-to-face meetings. Watabe emphasised during the interview that he found the most challenging part of the construction process was communicating with the Chinese volunteers, mainly because of the language difficulties. However, he "felt a bond among all the volunteers"[23] on completion of this project, and he came back to visit the school and his friends in 2009. A volunteer student commented that: "The research reminds me of that amazing experience. I remembered my motivation about design which I had when I started to study this subject."[24] Another student wrote: "This cooperation leaves a wonderful memory for me."[25] Whilst many problems could have been avoided if language had not been a drawback – the working language between the Chinese volunteer students and the Japanese volunteer students was English, which is not the first language of either side - but, after overcoming all the difficulties, this international cooperation strongly encouraged the students' motivation in architecture design and communication skills at a high level.

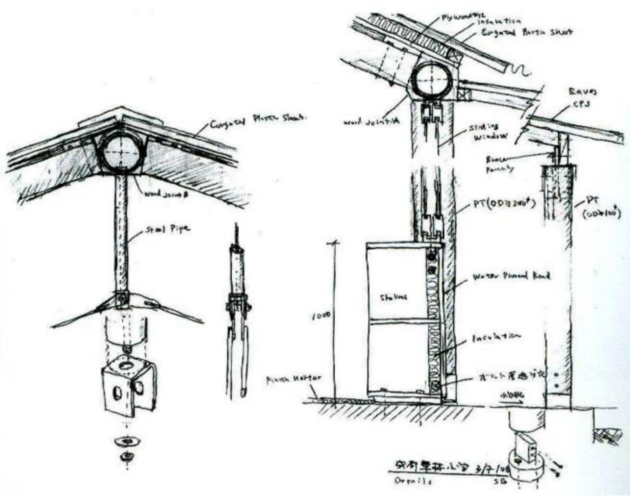
[22] Tanigaito, "Chengdu Hualin Elementary School.".
[23] Watabe.
[24] See Appendix C.
[25] See Appendix C.

FIGURE 4. 26. – FIGURE 4.27. A chair made from recycled timber panels, designed by Hironori Matsubara; A bin made from left over paper tubes, painted by the school students

4.2.3 Timescale

The majority of the construction materials and tools were purchased from local sources, thus making the transportation quick and easy. However, the project was delayed for a few reasons, especially because the volunteers from China did not have any previous experience of constructing a building from paper tubing. There were some errors in transferring the design concept to the construction due to insufficient knowledge and experience of using paper as a construction material. Ban states that “the hardship of the experience, which included having to teach Chinese students the most basic fundamentals of building, the frustrating lack of common language, and resistance to unaccustomed approaches to building and planning, [was] integral with its ultimate success”.[26]

[26] Ibid.



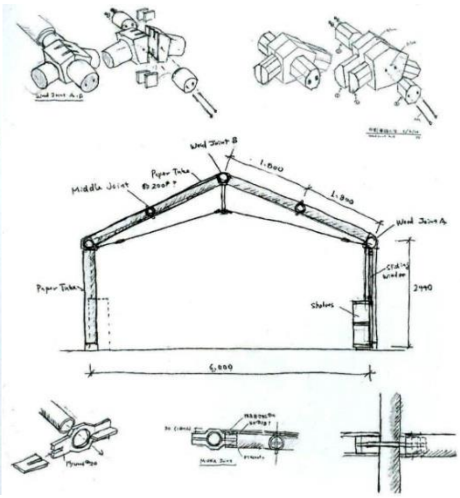


FIGURE 4.28. - FIGURE 4.29. Ban's sketch – details of the section;[27] Details of the timber joints[28]

There were also problems regarding the quality of the construction material. The company that manufactured all the timber joints brought a sample to the site first. According to Harano, they were solid timber joints of a good standard, so the team purchased all the timber joints from this company. During the later construction, the volunteer students found when they were drilling holes in the timber joints that they were hollow inside and could not be used because they needed to carry the weight from the building roof. There was not enough time to send these timber joints back to the factory and wait for replacement so the cavities were filled with glue to make the structure as strong as possible. This unexpected problem, however, delayed the project process for two days.[29]

FIGURE 4. 30. Timber joints were transported by a truck[30]

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[27] Shigeru Ban, "Ban's Sketch, Detail of the Section," (Tokyo: INAX, 2010).
[28] ———, "Ban's Sketch, Detail of the Timber Joint," (Tokyo: INAX, 2010).
[29] Watabe.
[30] Tanigaito, "Chengdu Hualin Elementary School.".

Other factors delayed the project, such as the convenience for the volunteers working outside normal hours during the Beijing 2008 Olympic Games, and not being able to work when it was raining. Due to cultural differences and different training backgrounds, there were also arguments between the partners. For example, when some Chinese volunteer students did not arrive at the site on time, this caused discontent among Japanese volunteer students.[31]

Ban came to the site four times in total, including his first visit and theattendence at the launch ceremony. The difficulties were overcome through the passion of the volunteers involved, and this resulted in just minor delays with the project. The project was completed to a good standard in 41 days, including one week to clear rubbles, from 2 August to 11 September 2008.

The life of the project is estimated at three to five years, which classifies it as a temporary building in China and allows for the rebuilding of Chengdu Hualin Elementary School using conventional materials. The initial plan was to transport the paper building to another place in Chengdu for exhibition, and also to serve as a symbolic structure to remember the great work of the volunteers. Whilst, the entire school was planning to move to a different location, and the original concrete school was to be demolished, both the paper school and the concrete building are still in use. According to Hou, who currently works as an engineer at Chengdu Railway Bureau, there is currently no plan to dismantle the paper school and no plan to move the school location.[32] Even though the reason for not dismantling the school is unknown, it proves that paper tubes can be a reliable material in architecture construction, as long as they are maintained in good condition and regularly tested.

4.2.4 Aesthetics

The Hualin School is located in the Chenghua area of Chengdu, approximately 20 minutes' drive from the city centre. The only remaining school building is a two-storey concrete building that is surrounded by residential areas and some skyscrapers. The large holes in the roof of the paper building caused confusion among the school teachers as they could not understand the purpose of them, with initial thoughts being that they were a symbolic pattern relevant to Japanese

[31] Deng.
[32] Lin Hou, in discussion with the author, December 2012.

culture.[33] However, the volunteer students appreciated the aesthetics of the design and, as Hou said during interview, “When we completed the construction, on one evening, we turned on the lights and all went to see it from the playground. In the dark, the light comes through from those large holes and it looked very beautiful.”[34] The large holes in the roof-support are a symbol of Ban’s architectural style. They can be seen in much of Ban’s work, including the Paper Dome in Japan (1998), the Paper Studio in Keio University Shoran Fujisawa Campus (2003), and the Paper Temporary Studio in Paris (2004). Aside from being a regular feature of Ban’s designs, they also apply functional use as they allow access for workers to the roof without having to climb atop the structure, and serve to illuminate the interior.[35]


FIGURE 4.31. - FIGURE 4. 32. A view of the surrounding environment; Volunteers working on the building roof[36]

The materials that were used in the building construction included paper tubes, cardboard, plywood, corrugated plastic sheets, galvanised steel sheets and PVC. The paper tube is the signature material of Shigeru Ban Architects, and the Japanese volunteers brought the materials with them in the plane when they first came to construct the full-size model of a residence dwelling in the Southwest Jiaotong University campus. One benefit of using paper tubes in this project is that the paper tubes are 100% recyclable, environmentally friendly and last for a relatively long time (5-20 years) if they are maintained in good condition. Secondly, using unusual material can help to avoid rising prices of traditional construction materials after earthquakes. Moreover, the paper frame structure reduced anxieties about earthquakes because of its lightness and warm surfaces compared to heavy concrete. According to the results of the questionnaires that were sent to the pupils, they enjoy the paper school as it provides them with a feeling of safety after the trauma they have been through. It also satisfies their functional needs and offers a warm and

[33] Teacher.
[34] Hou.
[35] Ban et al., *Shigeru Ban : Paper in Architecture*: 148.
[36] Tanigaito, "Chengdu Hualin Elementary School.".

friendly environment. Some parts of the construction were not made from recyclable materials, due to the pressure of responding to the disaster relief quickly and efficiently although some aspects, such as PVC windows and doors, can be re-used in other buildings once the school is dismantled.

TABLE 4.2. Construction materials used

Building Components	Material
Column	Paper tube
Wall	Paper tube
Partition wall	Board
Shelf	Plywood
Wall unit	Plywood
Ceiling	Plywood and form insulation
Roof	Corrugated plastic sheet
Roof ridge	Galvanised steel sheet
Window and door	PVC


FIGURE 4. 33. - FIGURE 4. 34. Paper tubes being stored inside a classroom in the concrete building; Paper tubes being treated by waterproof paint[37]

A year and a half after project completion, many paper tubes appeared to be mouldy at their base. The headmaster of the school sought solutions from the volunteer organiser, Yin, from Southwest Jiaotong University. Yin took the liberty of deciding to cut out the mouldy part and inserting a short metal column to support the rest of the paper tubes. Arguably, Yin should have proposed this solution to Ban Architects beforehand because: it does not follow the design aesthetics whereby the original design aimed to create a natural and lightweight study environment; and Ban Architects has rich experience in using paper as a construction material, and might have had a better solution than replacing the mouldy part with metal. Although the designer Yasunori Harano stated his desire to visit the school again to the author, scheduling problems led to none of the designers maintaining contact with the school or the Chinese volunteers.[38] In an interview with architect Watabe on 4 December 2012, the author asked his opinions on Yin's solution towards repairing

[37] Ibid.
[38] Yasunori Harano, in discussion with the author, September 2010.

the paper tubes. Watabe stated that this situation could have been solved during the design stage but, because it was such an emergency situation and was planned for no more three years of use, the maintenance of the building was not fully considered. He further explained that the whole paper tube could be replaced if necessary, depending on the building structure. The *Paper Studio*[39] had been used for six years before it was dismantled, and the students painted the paper tubes frequently with waterproof paint because its efficacy deteriorates under the rain and heat. Watabe believed that the paper tubes at Hualin School could have been maintained in a similar manner. Additionally, long crack appeared on the floor in one classroom, and Yin stated that this could be due to the concrete floor was not being treated evenly during the construction process. This was a result of the project having to be completed within such a short time, and being constructed by students instead of professional workers.[40]

FIGURE 4. 35. - FIGURE 4. 37 The end of a paper tube was damaged by the rain; The metal replacement; A crack appeared on the floor in one of the classrooms

[39] The Paper Studio was located at Keio University Fujisawa Campus, Fujisawa, Kanagawa, Japan. It was constructed by students at Keio University SFC and Shigeru Ban Laboratory and completed in March 2003.
[40] Yin.

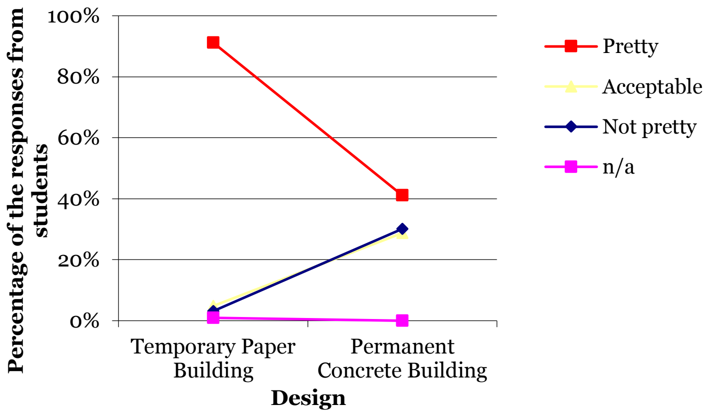


FIGURE 4. 38. Opinions on design

The user opinions concerning the aesthetics of the building were collected based on the general opinions of the building's appearance and the parents' feedback on the building. The results of the questionnaires demonstrate that 91.2% of the pupils think their paper classroom is aesthetically pleasing, while only 41.1% of the pupils think the same of the concrete building (Figure 4.38.).

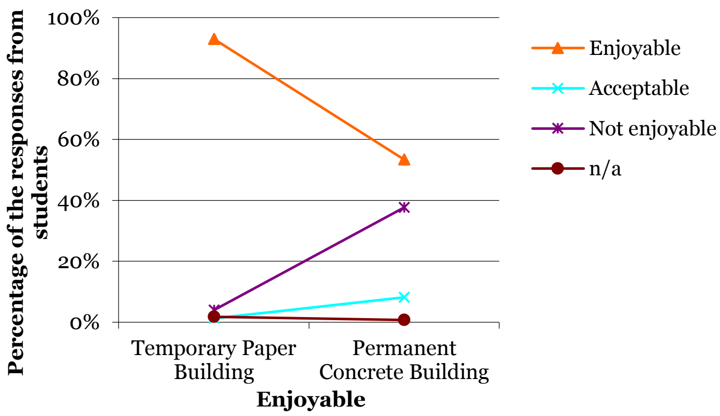


FIGURE 4. 39. Opinions on building experience

Questionnaire results also show that 93% of the pupils had an enjoyable experience whilst studying in the paper school, while only 53.4% of the pupils at Grade Six enjoyed studying in the concrete building (Figure 4.39.). There are two main reasons why the majority of students at Hualin School appreciate their paper school. Firstly, many of the students saw how the paper school was built while they studied in the concrete building and played next to the site. During this time, they became friends with the volunteer students and felt involved in this school project. Secondly, many of the students see their paper school as a novelty because it is the first temporary school made from paper in China and curiosity played a large part in their involvement in the project.

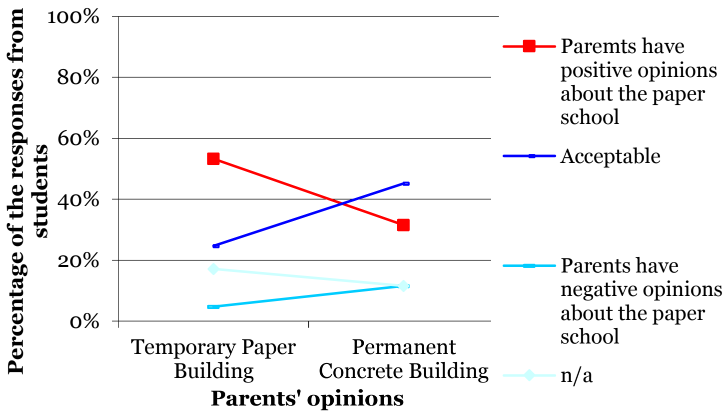


FIGURE 4. 40. Parents' opinions on design

The results from the questionnaires demonstrate that 53.3% of the parents had positive opinions of the paper school, and only 31.5% think the concrete building provides a good study environment (Figure 4.40.). School leader Mr Li stated that if the paper school had not been built, many of their students would have had to transfer to other schools and if that had happened, the parents would have to travel a long way to take their children to school and pick them up. Most of the students live in the residential areas surrounding to the school and, consequently, temporary paper school enabled them to stay with their teachers and classmates without disruption. Furthermore, the parents had a similar involvement with the construction of the school and were affected by the humanitarian work from volunteers, especially the Japanese volunteers, who travelled a great distance to the construction site.

4.2.5 Contributions

The contribution of Shigeru Ban Architects to the Hualin School project can be seen from both architectural design and social responsibility aspects. As the first school to be made of a paper frame structure in China, it has increased the awareness of transitional shelter designs among the general public, architecture schools and media. As mentioned in Chapter 3, a short film, *The Diary of the Paper House* by postgraduate student Xiao Zhen[41] from Beijing University, China, recorded the humanitarian story of Hualin School's construction process, and by winning the best film prize at the Third Student Video and Film Festival in China in 2008, it raised the public's interests in using recyclable materials in constructions. The elegant design is easy to understand, which was helpful for the volunteer students and teachers during the construction and the modular construction system was used efficiently in this project. The classroom windows and doors are detached from the main building structure, which makes deployment easy and efficient (Figure 4.30). This project also encouraged communication between the architects, architecture students and volunteers from Japan and China thus supporting architectural education and also offering new graduates an opportunity to turn their theoretical knowledge into reality. Since the Hualin School, Shigeru Ban's volunteer students have become a professional team with expertise in construction with paper tubes and cardboard. In book *Voluntary Architects' Network* (2010), Harano writes: "I could still share moments with all the other students when I felt that our challenges were urgently needed and sincerely wished to respond to that need. That's what I feel is the true reward that I gained through a sequence of volunteer activities."[42] After the Great Hanshin-Awaji (Kobe) Earthquake in 1995, Ban had established an NGO VAN (Voluntary Architects' Network) to organise disaster relief projects and activities. Their passion and commitment towards humanitarian work continues to benefit many countries, including Turkey, Sri Lanka, India and New Zealand.

FIGURE 4. 41. - FIGURE 4. 42. The crack shows that the PVC door and the paper tubes are detached; The frame structure of the building[43]

[41] Xiao Zhen was born in 1984 in Hubei Province, China, and she graduated with a Master Degree in Architecture from the Graduate Centre of Architecture at Peking University, China.
[42] Shigeru Ban et al., *Voluntary Architects' Network, Making Architecture, Nurturing People: From Rwanda to Haiti - Shigeru Ban + Keio University SFC Ban Laboratory* (Tokyo: Inakkusushuppan, 2010), 123.
[43] Tanigaito, "Chengdu Hualin Elementary School.".

Furthermore, the Hualin School project encouraged architectural education by providing an opportunity for international co-operation. An online questionnaire sent to the volunteers through Harano and Hou received seven responses, of which five were completed by Japanese volunteers and two by Chinese volunteers. The total number of Japanese volunteers was 25, thus a 20% completion rate renders the results somewhat valuable. The results show that the volunteers were able to understand and follow Ban's design concept clearly. Their understanding in architecture was improved and their construction skills developed. Moreover, they enhanced their skills of communication by working as a team towards the same aim. Although many unexpected issues occurred, such as the low quality of some of the construction materials, pressure from the tight schedule and cultural differences, the volunteers enjoyed their experience of the construction process, learnt from other volunteers and built their motivation in design and co-operation. Appendix C provides a list of data collected through the questionnaires, including quantitative figures showing the general background of the volunteers and qualitative information showing how the volunteers described their experience.

4.2.6 Limitations

The project management team involved many organisations and individuals, including Shigeru Ban Architects, BMA Beijing Matsubara and Architects, the Faculty of Architecture at Southwest Jiaotong University, Chengdu Education Bureau, Shenzhen Re-Tumu Professional Volunteer Group and individuals, such as Tao Zhu from the Faculty of Architecture at the University of Hong Kong. A lack of project management appeared throughout the construction, which was particularly evident in organising the funding bodies. As a humanitarian project and although the Hualin School was the client, the project owner was the Chengdu Education Bureau and, therefore, the stakeholders involved two organisations, leading to a lack of funding management.

A further limitation of Hualin School is the lack of clarity regarding the lifespan of the building. In a conversation between Shigeru Ban and Brad Pitt,[44] translated by Naoko Shinogi, Ban stated that the school was a permanent building.[45] Ban further

[44] Brad Pitt was born on 18 December 1963 and is an American actor and film producer. He has a substantial interest in architecture and humanitarian work. He founded the Make It Right Foundation in 2006 to build affordable, high-quality homes for people in need.
[45] Ban et al., *Voluntary Architects' Network, Making Architecture, Nurturing People: From Rwanda to Haiti - Shigeru Ban + Keio University SFC Ban Laboratory*: 143.

explained that "they're permanent structures. The construction was very cheap because they were built by Japanese and local Chinese students."[46] According to Yin, Ban was commissioned to build a temporary building, and Ban stated that the building could last up to 20 years if it was maintained in good condition.[47] If this building was initially built as a permanent structure, there are no clear instructions or recommendation from the architects in respect of how to replace the building components when necessary.

4.2.7 Recommendations

- At present, no decision has yet been made regarding the final destination of the paper school. There is clear evidence that the school intends to use the paper building for as long as it remains. The school leader should consult Shigeru Ban Architects for information on how to maintain the building in the future and how to dismantle the building if applicable.

- The information gathered from this case study suggests that encouraging more communication between the designers and the school leaders is important during the post-occupancy evaluation (POE). The purpose of POE is to engage the building users and the designer to provide more appropriate designs in future projects and make changes where necessary.

- Shigeru Ban Architects evaluates their disaster relief projects through questionnaires and revisits, including the Container Temporary Housing in Japan and the Transitional Cathedral project for Christchurch, New Zealand.[48] The main reason for the company not evaluating the Hualin project until the end of 2012 could be due to difficulties in communication. Watabe states that he and Harano are the only two staff in Ban's office who were involved in the Hualin project, and it is unlikely that any volunteer from Japan would visit the school in the near future. They only evaluated the project with regards to the materials used, time spent and other descriptive information, and not from a self-critiquing perspective to analyse the project management.[49]

[46] Ibid., 143-45.
[47] Yin.
[48] Watabe.
[49] Ibid.

An interview was arranged on 4 December 2012 with Watabe regarding the completion of the evaluation questionnaire for the Hualin School. The only performance indicator for which Watabe selected disagree was the use-time of the building. Apart from this, he selected strongly agree for all other indicators. Based on the outcomes of the user questionnaires and field research, the author ranked the indicators from the users' perspective and compared the results with the designer's opinions.

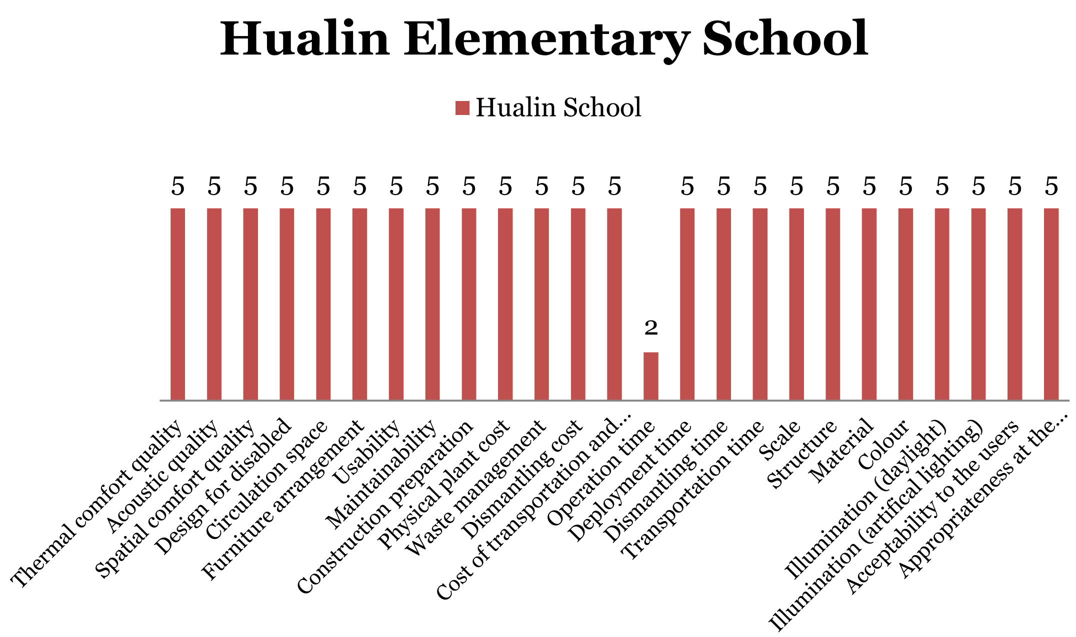
The author will continue to liaise with all key stakeholders in the Hualin School and further observe the school's final decision on the building. Information and feedback will be passed directly to the architect, Harano, for further discussion and critique.

TABLE 4.3. Post-Occupancy Evaluation of Chengdu Hualin Elementary School – A Conceptual Model

A. General Information

Project name	Chengdu Hualin Elementary School
Client	Chengdu Hualin Elementary School
Designer	Shigeru Ban Architects (Shigeru Ban, Yasunori Harano)
Function	Specific function – school building (non-commercial)
Type of architecture	Building
Location	Chengdu City, Sichuan Province, China
Date of implementation	08/2008

B. Weighted Section Scores (ranked by the designer)

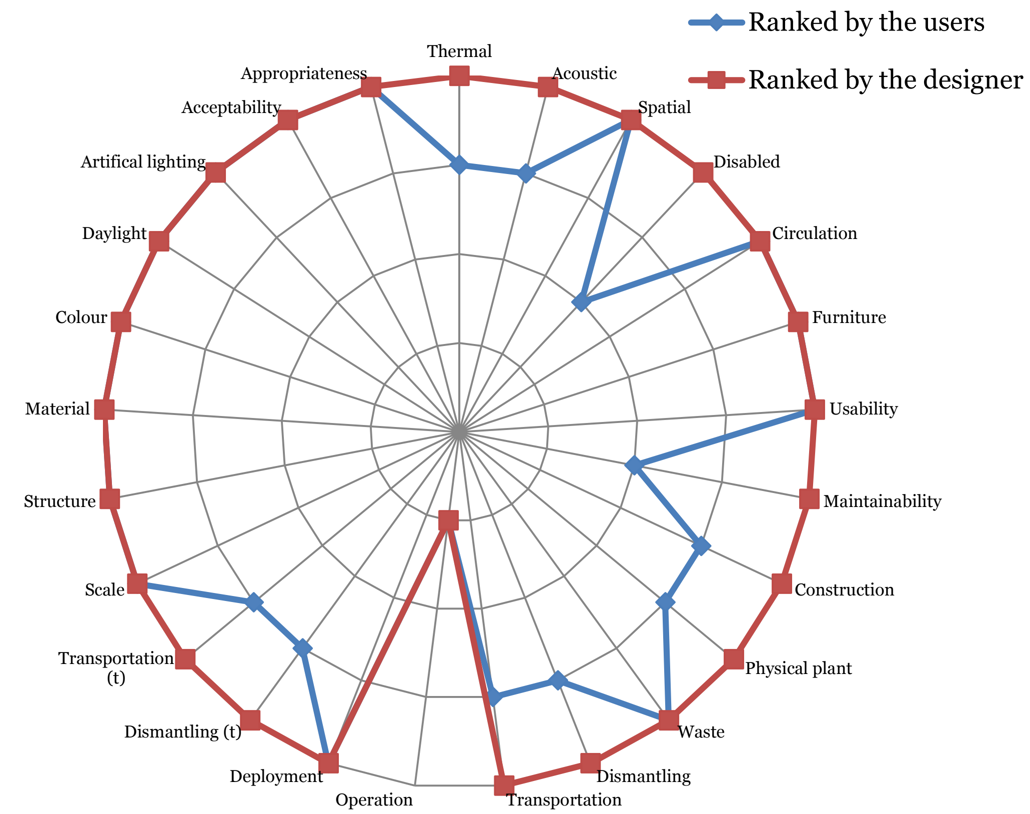


$$\text{DQIdesigner} = \frac{\text{Function+Finance+Timscale+Aesthetics}}{25\times5} = \mathbf{0.98}$$

$$\text{DQIuser} = \frac{\text{Function+Finance+Timscale+Aesthetics}}{25\times5} = \mathbf{0.89}$$

Both results 0.98 > 0.60 and 0.89 > 0.60 indicate that the Hualin Elementary School is a successful demountable building project.

C. Average Section Scores

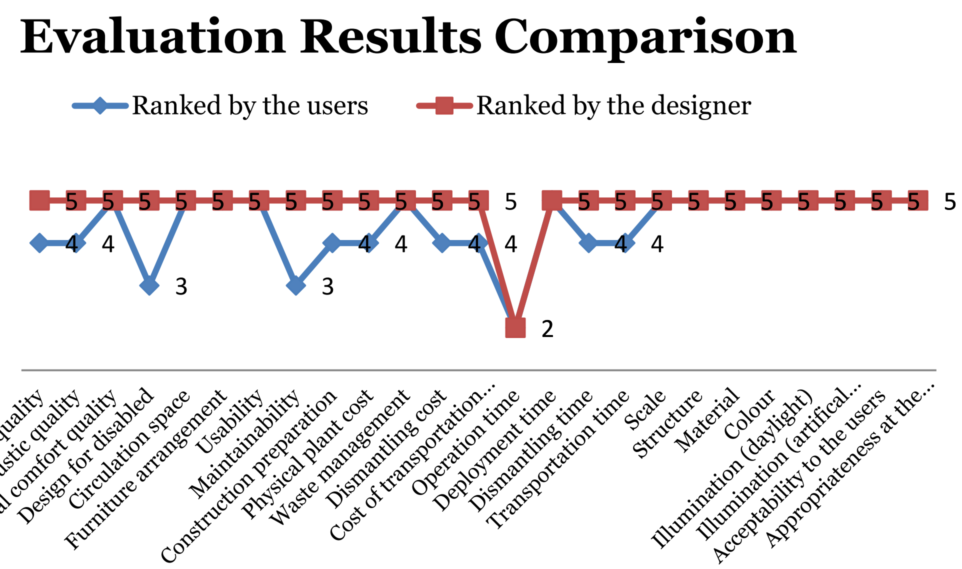


D. Opinions from users (Likes/Dislikes)

Likes	Dislikes
Material (paper tubes)	Ceiling design
Colour	Ventilation
Layout	
Windows	
Courtyard	
Volunteers	

E. Evaluation Results Comparison

The visualisation below compares the evaluation results of project value weighting.
The building passed on 24 (96%) of the 25 factors marked as fundamental for this project.



F. Key Interpretations & Next Steps

Contributions:

- This project is the first school to be made of a paper frame structure in China and it has increased the awareness of transitional shelter design among the general public, architecture schools and the media.
- It encouraged communication between the architects, architecture students and the volunteers from Japan and China, thus supporting architecture education and also offering new graduates an opportunity to turn theory into reality.
- Shigeru Ban's volunteer students' team is a professional team with expertise in construction by paper tubes and cardboard. After the Great Hanshin-Awaji Earthquake, Ban established an NGO VAN (Voluntary Architects' Network), to organise disaster relief projects and activities.
- The design is elegant and easy to understand, which was helpful for the volunteer students and teachers to follow during construction.
- The classroom windows and doors are detached from the main building structure.
- It can be argued that a modular construction system was used efficiently in this project.

Limitations:

- A lack of project management appeared throughout construction, particularly evident in organising the funding bodies. A reason for this is because this was a humanitarian project; even though the Hualin School was the client, the project owner was the Chengdu Education Bureau.
- The lifespan of the building is unclear. If this building was initially built as a permanent structure, there are no clear instructions or recommendation from the architects in respect of how to replace the building components when necessary.

Recommendations:

- Encourage more communication between the designers and the school leader, in order to make the best decision with regards to the final destination for the paper school.

Next Steps:

- Liaise with the designer and the school leaders for further maintenance solutions.

4.3 Exxopolis – an Architects of Air Project

Architects of Air is a small company that designs and tours pneumatic structures and is based in a 372 m^2 former textile workshop in Nottingham, UK. Artist and company director Alan Parkinson started the company in 1992. The current staff includes managing director Mado Ehrenborg, workshop supervisor Jon Gatt, and workshop and operations manager Rich Spiby. The company employs around 15 temporary staff for touring and construction each year. All the structures are known as *luminarium*, a word used by Parkinson to meaning colourful and bright. The first luminarium, *Eggopolis*, was built in 1990 in Nottingham with help from volunteers and community service workers from the Probation Service. Eggopolis toured the UK together with learning-disabled performers from Springwood Day Centre, and became a feature of Nottingham play-schemes before becoming the first structure toured by Architects of Air. This laid the foundations for Architects of Air's luminaria being visited by over two million people in 38 countries around the world. The most common clients of Architects of Air's structures are art galleries, charities and organisations such as the British Council that are interested in promoting cultural events.


FIGURE 4.43. - FIGURE 4. 44. Newark environment (1988); Eggopolis (1990)

Sixteen unique luminaria have been designed to date, including: Eggopolis (1992); Megoopolis (1995); Luminarium III (1996); Luminarium IV (1997); Archipelago (1999); Levity (2000); Arcazaar (2001); Ixilum (2002); Luminarium V (2003); Amozozo (2004); Triaxial (2004); Levity II (2005); Levity III (2007); Amococo (2008); Miazozo (2010) and Exxopolis (2012). In the past, Parkinson expressed his design ideas simply by using drawing boards and continual experiments in the workshop and factories. More recently, he has used Rhino 3D as the main design tool to develop more precise drawing plans. Each structure is constructed from around 20 elements that are cut and glued together in the studio and zipped together on site. The natural light shining through the coloured plastic forms the luminosity of colour inside all structures and creates a vivid environment for visitors.

Architects of Air was discovered here through an internet search, and an email was sent to the company on 28 October 2010 expressing research interest in their projects. Parkinson replied quickly and a Skype interview was arranged on 8 November 2010. There are few documented materials recording the work of Architects of Air although limited information can be found in books such as *Textiles, Polymers and Composites for Building* (2010). Here, John Chilton writes:

> Although not strictly textiles (being fabricated from coloured PVC), the 'luminaria' of Architects of Air, Nottingham, UK (Architects-of-Air, 2008) demonstrate the sculptural appeal of inflated forms. In this case the installations may be experienced in a different way, from the outside as is more usual, but also more intensely on the inside, where one may encounter the full impact of the strong colours used in the surface envelope.[50]

In order to obtain an insight into the manufacturing process of the structures, the author visited the studio at the Oldknows Factory, Egerton Street in Nottingham on 27 April 2011, and later attended the team testing one of the structures in the Sports Centre at the University of Nottingham. In 2012, the team was planning a new design, Exxopolis, in partnership with Lakeside Arts Centre, Nottingham and, therefore, the company was returning to its birthplace in June to celebrate the twentieth luminarium. After careful consideration Exxopolis was selected as a case study, and the exhibition site was visited from 1–3 June 2012. Before the visit, a questionnaire containing 17 individual questions regarding the functional performance of Exxopolis was designed and agreed with both Alan Parkinson and Mado Ehrenborg. In an email to the author on the 22 May 2012, Ehrenborg suggests:

> I also think it will be interesting for you to have the contact with the people filling in the questionnaires. I think best is actually when visitors have put their shoes back on and have just exited the reception area. We need visitors to leave the reception area as soon as possible so that we have enough space for new visitors.[51]

[50] John Chilton, "Tensile Structures - Textiles for Architecture and Design," In Göran Pohl, *Textiles, Polymers and Composites for Buildings* (Oxford; Philadelphia: Woodhead Pub. in association with the Textile Institute, 2010), 249.

[51] Mado Ehrenborg, Email, May 2012.

With the agreement regarding the procedure for the questionnaires, 200 hard copies were prepared and the Survey Design[52] application, which is a set of survey software integrating questionnaire designs with data input was downloaded onto an iPad.
As with previous designs, Exxopolis takes its inspiration from natural geometry and Islamic architecture, and intends to provide a space for contemplation. The design of the principal dome was inspired by the circular space of the octagonal chapter house of Southwell Minster in Southwell, Nottinghamshire.

FIGURE 4. 45. - FIGURE 4. 46. Exxopolis (2012); A choir performance inside Exxopolis

The local Arts Centre community groups joined the Windows Projects[53] workshops to make the intricate windows of the Exxopolis Cupola. The participant groups in the workshops were Architects of Air, the Textile Workshop Nottingham, The Lenton Centre, Nottingham and Nottinghamshire Refugee Forum, Lakeside Arts Centre, Meadows Partnership Trust and Meadows Art Group, East Midlands Parent Bloggers, and Dunkirk and Lenton Partnership Forum. The Cupola windows are made up of small shapes of coloured plastic, designed to create a “stained-glass” effect. The shapes use the Penrose tiling discovered by mathematician and physicist Roger Penrose, and this irregular 5-fold patterning echoes the three dodecahedral domes.

[52] This iPad application was developed by Ringrove Limited. The software operation is divided into three steps: survey design, data input and survey results check.

[53] The Windows Project Workshops began from 2 April and allowed a period of five weeks before the windows were ready for insertion. The inserting of the windows into the main dome of Exxopolis took place from 7 May with the full-scale trial inflation taking place. The costs of participation in this project, regarding the requirements for plastic, glue, masking tape, steam rollers, scissors, knives and polythene sheets, were mainly supplied by Architects of Air.


FIGURE 4. 47. - FIGURE 4. 48. The principal dome of Exxopolis; The intricate windows of the Exxopolis Cupola

4.3.1 Function

The main function of Exxopolis, as with all the other luminaria exhibited in the past is to provide an interior space for visitors to walk around and experience a colourful and bright environment. All structures welcome the general public, including disabled people, such as those in wheelchairs or needing special care. The wheelchair wheels are checked by the staff before entry, in case there is anything sharp that might damage the PVC plastic. Special events, including live music, yoga and story reading, can be arranged, according to the project promoters' requirements. A small inflatable structure is attached to the main design as a reception place for visitors to change their shoes and store their prams. According to the project manager, Mado Ehrenborg, the storage space needs to be as uncrowded as possible because the entrance and the exit of the structure are in the same place. A red triangle directs people to queue before entering the structure. After taking off their shoes at the reception area, the visitors walk into an entrance where a member of staff delivers an introductory speech to welcome guests and emphasise the safety issues. This entrance area has doors at both sides, one connecting with the reception area and one connecting with the main exhibition area. During the exhibition, two staff members stay outside the entrance and one staff member stays by the internal entrance to make sure the two doors are not open at the same time, which could cause the structure to deflate.


FIGURE 4. 49. - FIGURE 4. 50. The main entrance; The second entrance

The results of the questionnaires indicate that, during the exhibition at the Lakeside Arts Centre, there were slightly more female visitors (53%) than male visitors (47%). The majority of the visitors were aged from 31 to 40 and did not have any architectural training (Figure 4.52. - Figure 4.53.). Eighty per cent of the visitors came to the site from Nottingham, and the majority of them had heard about the exhibition from family and friends (Figure 4.54. - Figure 4.55.). Among the visitors, 39% of them had visited a luminarium before (Figure 4.56.). Most of the visitors came for both the festival and the luminarium (Figure 4.57.). The questionnaire results also demonstrate that 76% of the visitors did not feel crowded inside the structure, although 11% of the visitors did feel crowded during their visit (Fgure 4.58.). When Exxopolis opened, from 1–10 June, the weather in Nottingham was rainy and windy most of the time, so the number of visitors was not as large as the Arts Centre expected. Those visitors who felt crowded stated that this was because, on some occasions, there were many children inside and they were running around or shouting. The design team and the Arts Centre were aware that this might be a problem for elderly visitors, so they arranged adults-only sessions on both the 7 and 8 June from 6:00–7:30pm for those visitors who would prefer a quiet environment. Interestingly 13% of the visitors did not notice whether it was crowded or not because they were immediately attracted by the fascinating colours inside the structure and they were unaffected by other visitors' activities.

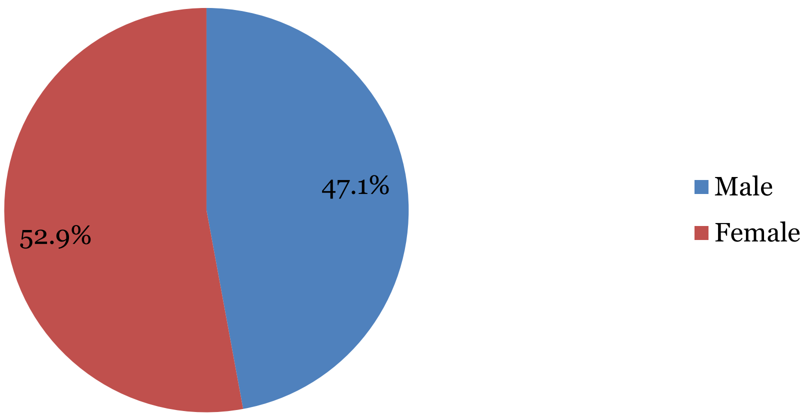


FIGURE 4. 51. Gender

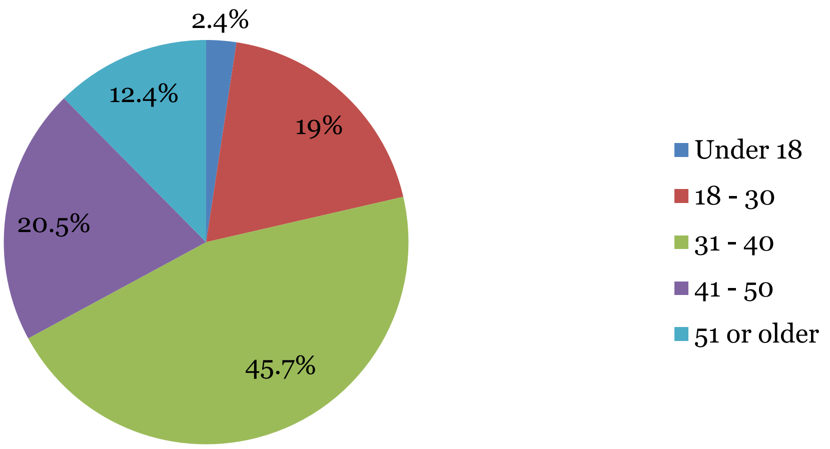


FIGURE 4. 52. Age group

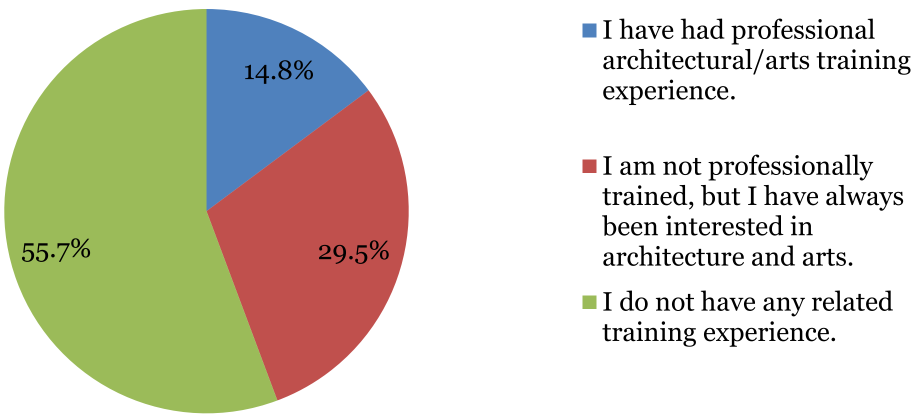


FIGURE 4. 53. Architectural/arts traning experience

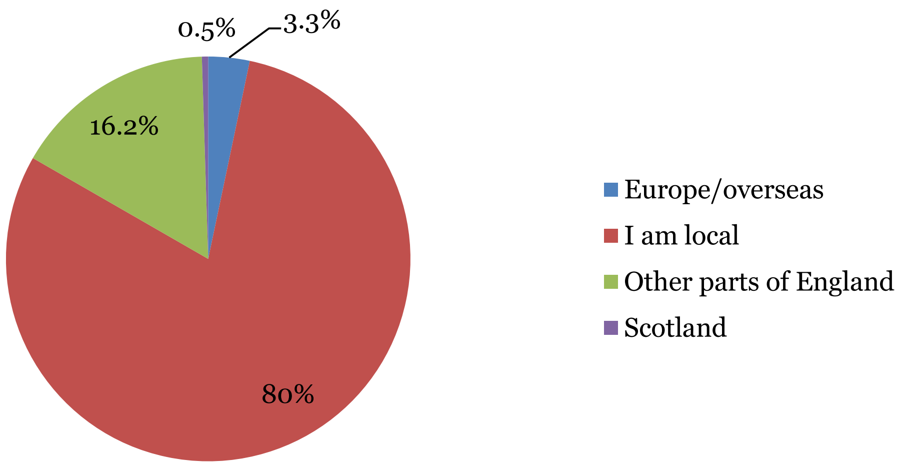


FIGURE 4. 54. Travelling

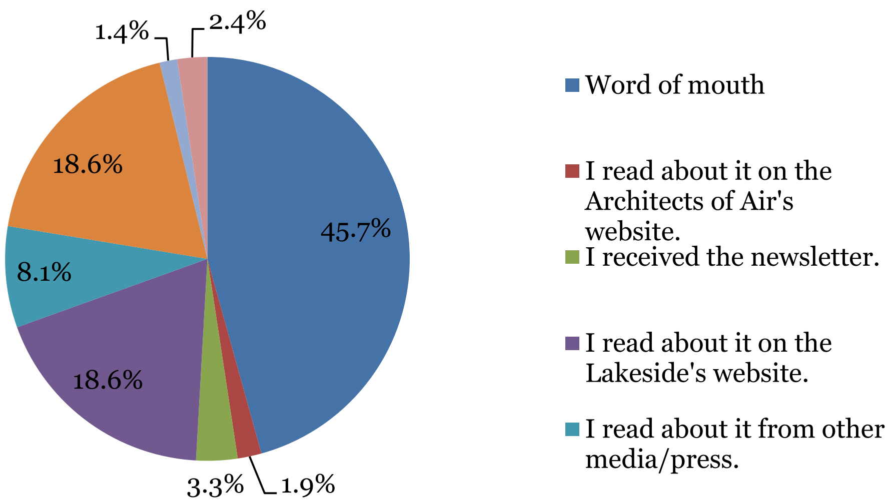


FIGURE 4. 55. Where did you hear about the Exxopolis Luminarium

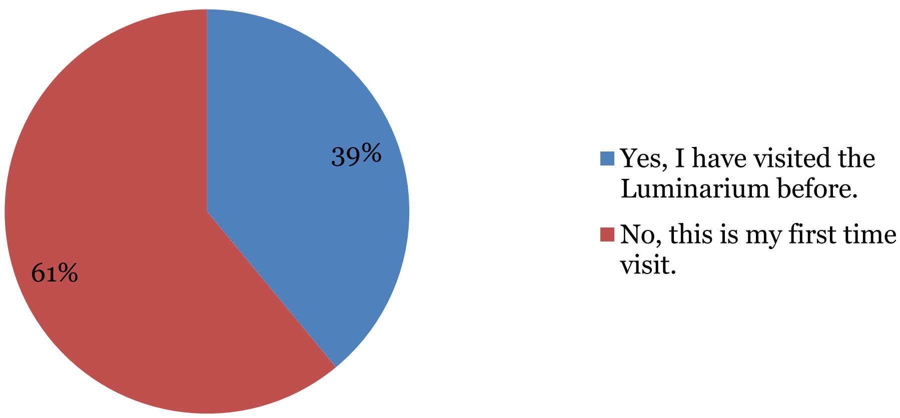


FIGURE 4. 56. Previous experience

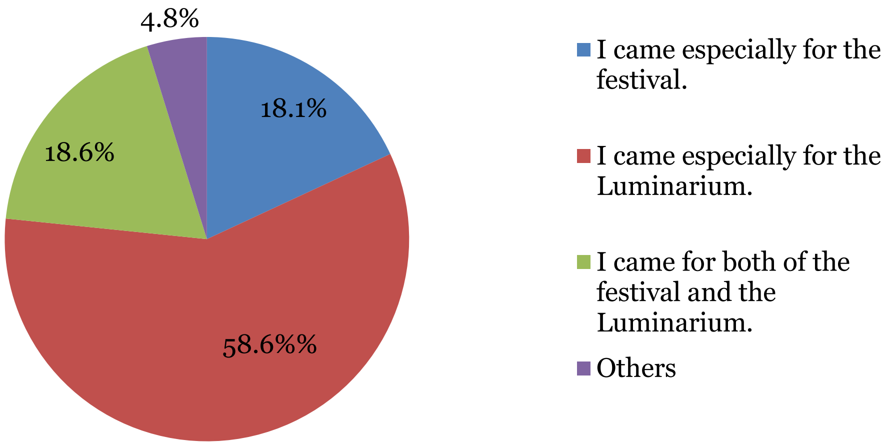


FIGURE 4. 57. Attending events

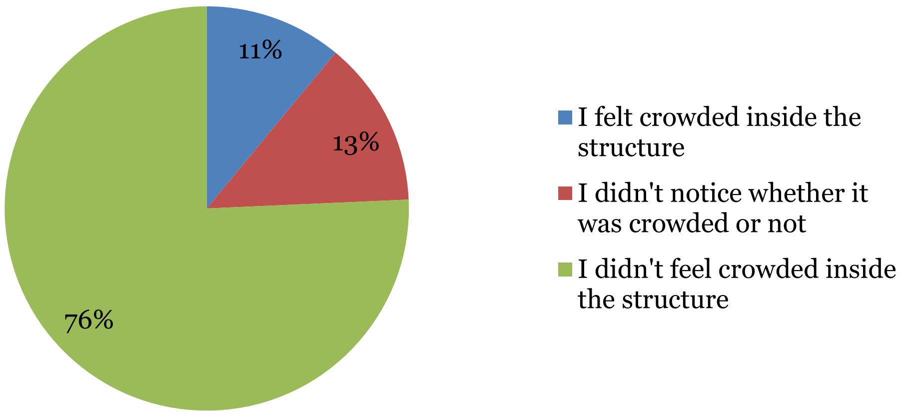


FIGURE 4. 58. Did you feel crowded inside the structure

FIGURE 4. 59. - FIGURE 4. 60. A wheelchair user inside Exxopolis; Visitors enjoy their experience inside the structure

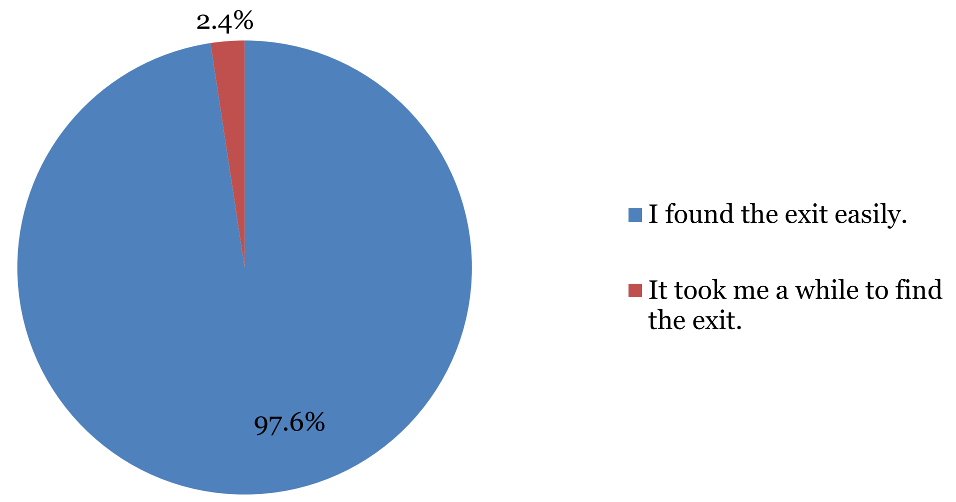


FIGURE 4. 61. Did you find the structure exit easily

There are no emergency lights to direct visitors inside the structure because, according to Parkinson, this would disturb the experience inside the structure. The circulation space is combined with an exhibition area that is also the pathway to the exit. However, the results of the questionnaires indicate that 97.6% of the visitors found the exit easily and only 2.4% took a while to find the exit (Figure 4.61).

There is no furniture inside the structure because, it might damage the structure from inside and, the internal space is limited. Visitors are strongly encouraged to sit anywhere to merge into the colourful surroundings. According to the Architects of Air Promoter's Kit, it is the promoter's responsibility to provide furniture in the reception area. This includes a table and chair for ticket sales, a waste bin, at least 16 chairs for visitors to sit on when changing their shoes, and shoe storage, such as shelves, racks or tables.

An elderly female visitor said: "The floor was too bumpy for me; I thought about bringing a pair of soft shoes that I wear on the wooden floors."[54] The author found out through their conversation that this visitor had an operation on her ankle in 2011 and, although she was not disabled, she found it difficult to balance herself inside Exxopolis, particularly because there was nothing that she could lean on. The reason for this is that the structure was set up on grass without any foundations, and the ground is uneven. Many visitors described the inside of the structure as "freezing" because they experienced the structure without shoes on, and the structure touched

54 Visitor, in discussion with the author, June 2012.

the ground without anything in between. Soft shoes could be supplied by the promoters for a more comfortable experience.

4.3.2 Finance

The main costs of each luminarium include materials, manufacturing, labour, transportation and touring. For the domestic exhibitions, the entire structure, all equipment including fans and tools, barriers, two banners of 6.60m × 0.83m and three display boards of 0.8m × 0.6m[55] can be stored and transported in a van. If there is an international request for the exhibition, the structure and equipment can be transported by ship or air. Sometimes, the transportation fee can be avoided, for example, in an email to the author on the 24 September 2012, Parkinson stated, with regard to the transportation of Miracoco, exhibited from 26–27 October in Wuhan, China that:

> In the end the structure was sent by air as the contractual formalities were not completed in time for it to be sent by sea. The air freight was very quick of course and the importation took no time as it was imported by the British Council as "diplomatic goods" - that way it was not checked by the customs.[56]

FIGURE 4. 62. A white van was used to transport the whole structure and equipment

According to the Promoter's Kit, Architects of Air recommends to the promoters that the average entry fee is about £3/$5 per person and it should be the same cost for

[55] The banners and display boards are used to indicate the name of the structure and general information about Architects of Air.
[56] Alan Parkinson, Email, September 2012.

adults and children.[57] On some occasions, entrance is free of charge, as was the case with Miracoco in Wuhan, China from 26–27 October during the UK Now festival.[58] The event was jointly hosted by New World China Land Limited (NWCL) and the Cultural and Education Section of the British Embassy, and was unveiled at the Central Park in Wuhan Changqing Garden. According to the information from NWCL, no fee was charged for the public to visit Miracoco.[59]

4.3.3 Timescale

Most of the activities are held in summer and autumn, because the bad weather in winter can be a threat to the structures. Jon Gatt, the workshop supervisor, and Rich Spiby, the workshop and operations manager, work at the studio in Nottingham all year round and they are responsible for hiring most of the temporary workers. Alan Parkinson and Mado Ehrenborg live in France throughout the year. Parkinson primarily works on the design process, and sometimes his assistant helps him with using computer software to model the design concept.

Normally, each luminarium requires a workforce of five to six people and about four to six months to complete. Although it is desirable that the temporary workers have craft skills it is not necessary that they have any professional training in arts and architecture. Anyone with a basic understanding of crafts can be trained easily and work rapidly, although the experience and skills of the workers are reflected in the detail and the aesthetics of the structure.

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[57] Architects of Air, "Architects of Air Promoter's Kit," (2012), 2.

[58] The UK Now festival presents recent artistic work, both classical and contemporary, to audiences in China. The festival took place from April to November 2012 in 17 cities across China. The events included a wide range of art forms including design, architecture, film, music, dance, fashion, digital art, theatre and literature.

[59] New World China Land Limited, "“UK Now-Architects of Air Miracoco” Exhibition Opens in Wuhan Changqing Garden - 26/09/2012," http://www.nwcl.com.hk/html/eng/news/news_detail.aspx?sIAtlp20W0Xw0G644TaXC2siOjtA%2f8KMVCb4V%2fyWXOM%3d=tlp20 (assessed 11 October 2012).

FIGURE 4. 63. - FIGURE 4. 64. Parts of the structure being prepared in the studio; Electronic fans

On visiting Exxopolis on 1 June 2012, a team of ten people, under the guidance of Rich Spiby, unpacked the structural components from the van at 9:00am. They identified the approximate location of each packed component before unfolding them. Once all the unfolded plastic sheets were laid on the grass, the team hammered metal pegs into the ground and tied the components onto the pegs. Once this work was completed, three electronic fans were connected and they began to inflate the structure. It took a total time of two hours, from arrival to full inflation, with the latter process taking 20 minutes. In the evening, for safety reasons, the structure was deflated and left on the ground. The deflation process also took around 20 minutes, and occurred after the staff checked there was nothing left inside the structure.

FIGURE 4. 65. - FIGURE 4. 66. The team prepares the structure before inflation; Metal pegs are used to tie the structure to the ground

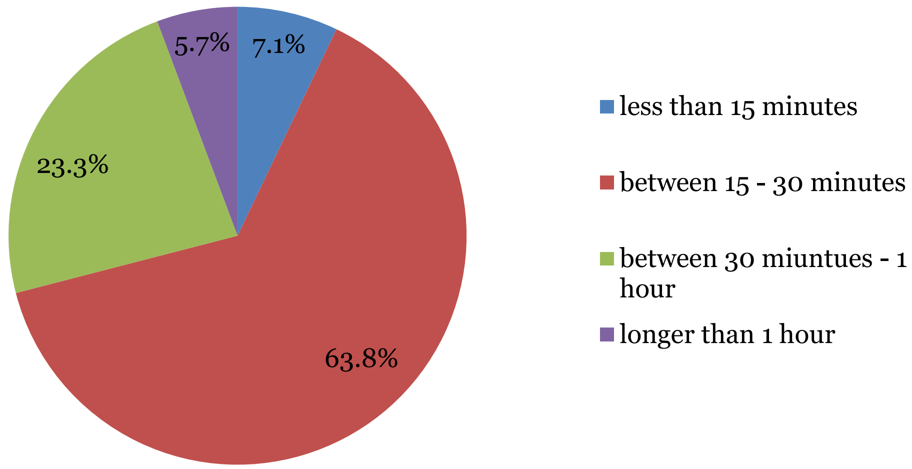

FIGURE 4. 67. How long did you stay inside the structure

The opening hours varied from day to day, according to the promoter's requirements and often there were longer opening hours at the weekend, due to higher visitor demand. Typically, the structure was open for about six hours per day, with the structure closing at least 30 minutes before sunset to ensure an adequate light level inside. The results of the questionnaires indicate that 64% of the visitors spent 15 to 30 minutes inside Exxopolis during their visit, and 23% of them spent between half an hour and one hour exploring the structure (Figure 4.67.). As with Exxopolis, all the other luminarium structures can be constructed and inflated rapidly by a small team. Although the visitors spend a relatively short time inside the structure, because of the limited space and activities, Exxopolis offers the visitors an unforgettable experience with its vivid and luminous colours.

4.3.4 Aesthetics

The completed Exxopolis occupies and area of half a football field and rises to the height of a three-storey building. Exxopolis took six months to build, with 55 people contributing to its manufacture. It used 3,000m^2 of plastic in its construction of 9,000 individual pieces joined by 6km of seams. The main material used for Exxopolis and all the other luminaria is a PVC plastic that has been exclusively produced over the last 20 years in La Tour du Pin, France by French manufacturer Ferrari for Architects of Air.

FIGURE 4. 68. The coloured PVC plastics are stored in the studio in Nottingham

The commonly used colours in the luminaria are red, yellow, blue and green. Parkinson explained that the colour green is used less than the others, because the illumination of red and yellow creates orange, red and blue creates purple, and yellow and blue creates green. Through the reflection of natural light from outside, a wide range of colours are created. Different colours have been used in the past, but they did not work well.[60]

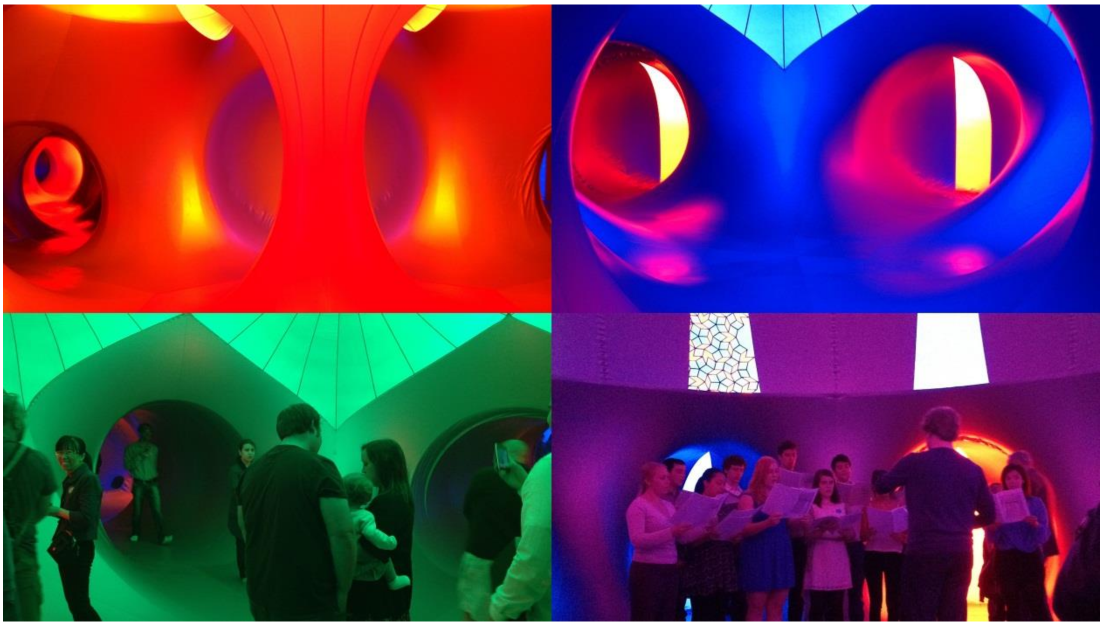

FIGURE 4. 69. - FIGURE 4. 72. Red dome; Blue dome; Green dome; Purple dome

[60] Parkinson.

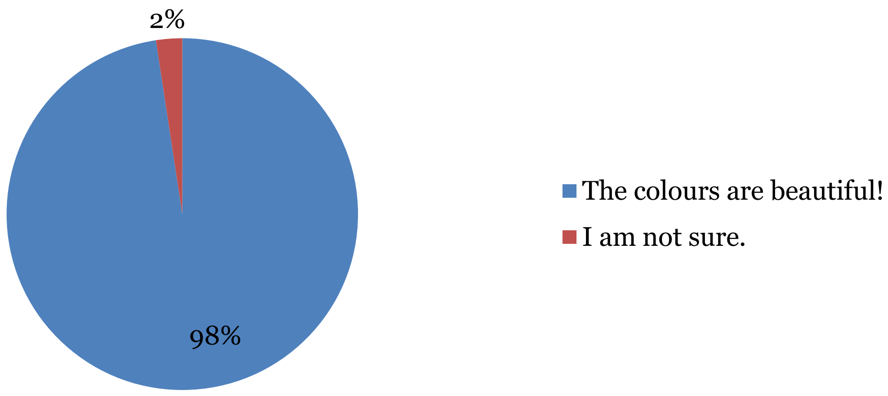

FIGURE 4. 73. Visitors' opinions on colours

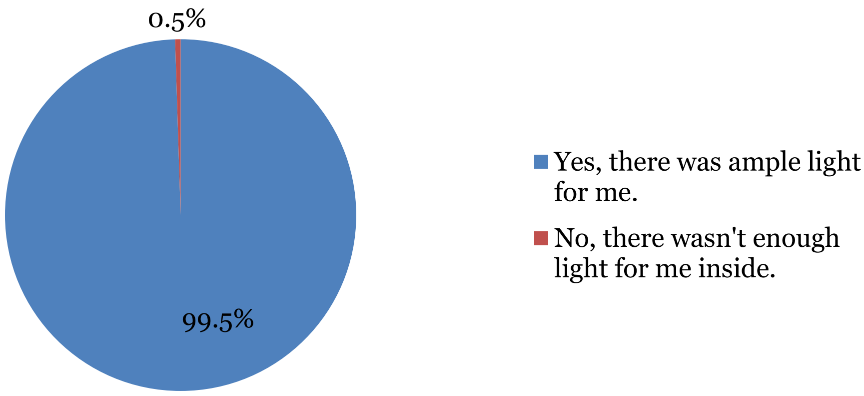

FIGURE 4. 74. Visitors' opinions on light

A highly rated 98% of the visitors thought the colours inside the structure were beautiful, and 99.5% of them said there was enough light inside the structure (Figure 4.73. – Figure 4.74.). A visitor commented that "blue [colour] is too dark for the children".[61] Another visitor commented that his child started to cry when they went in, and they had to come out because the child was scared.[62] Although the majority of the visitors had an enjoyable time in Exxopolis, the question is raised of whether it is possible for a design to be suitable for everybody. Adults, older children and small children perceive their surrounding environments differently and, therefore, a luminarium often has an opposite effect on children than it has on adults. Adults find a luminarium a calm space that encourages reflection, whereas children are stimulated and display and an energetic response on discovering the exciting new environment. Children enjoy visiting a luminarium, but they have to be supervised

[61] See Appendix D.
[62] Visitor.

to avoid them disrupting the experience of others. Child visitors are encouraged to be calm and to stay with their responsible adults. Children are instructed not to run around or jump against the walls as this would spoil the ambience and could be a threat to other visitors and people with disabilities. Architects of Air recommends to the promoters that children under 16 years of age are admitted only if accompanied by an adult. There should be no more than four children to one adult, and only visitors over 18 may be responsible for younger children.

The music used for Exxopolis when exhibited at Lakeside was created by Irish musician, artist and filmmaker, David Bickley,[63] who created a poetic and wondrous sound environment for the visitors. Two visitors who completed the questionnaires commented that "maybe you could have different music for different colours [domes]". [64] This is an interesting idea as the music could be contextualised according to the colour although it would require the structure to be on a much larger scale in order to avoid the interruption of music from one dome to another.

In terms of the acceptability to the promoters, many documents are available for use as references, enabling them to obtain an exhaustive understanding of how to best use the structures and work with the Architects of Air staff. These documents include: *Stewards Management* – guidelines to select and plan the role of the stewards; *Stewards Guidelines* – guidelines to be handed out to the stewards; *Technical Manual* – guidelines that describe all technical aspects; *Hosting Performances and Workshops* – guidelines to provide information about possible interactive interventions; *Safety Manual* – a document containing the safety certificates; *Media Kit* – media guidelines, copies for print and links to videos that can be downloaded; *Sponsorship* – guidelines to sponsorship possibilities; and *Accessibility* – guidelines to optimise accessibility. Apart from the relevant documents, the managing director delivers a 30-minute workshop to the promoter's staff to address any important issues that may arise during the exhibition. At least two staff members from Architects of Air stay on site throughout the exhibition to monitor the event. Jayne Willox, who has been responsible for many tours in Europe, states that staff walk around the structure during the exhibition time to ensure the visitors' safety. Sometimes, tiny holes appear on the structure, and a temporary solution is the use of adhesive tape to cover them.[65]

[63] David Bickley is currently based in West Cork, Ireland; he was educated at the Bournemouth College of Art and Design and later at West Surrey College of Art and Design.
[64] Visitor.
[65] Jayne Willox, in discussion with the author, April 2011.

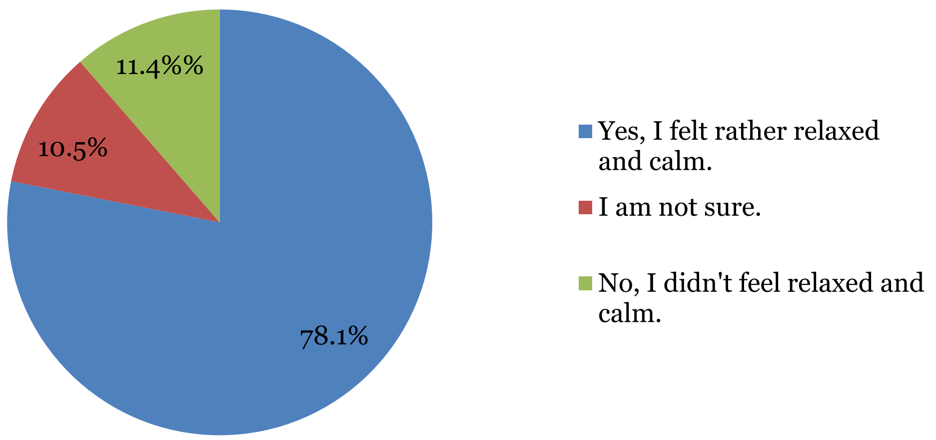

FIGURE 4. 75. Did you feel relaxed and calm inside the structure

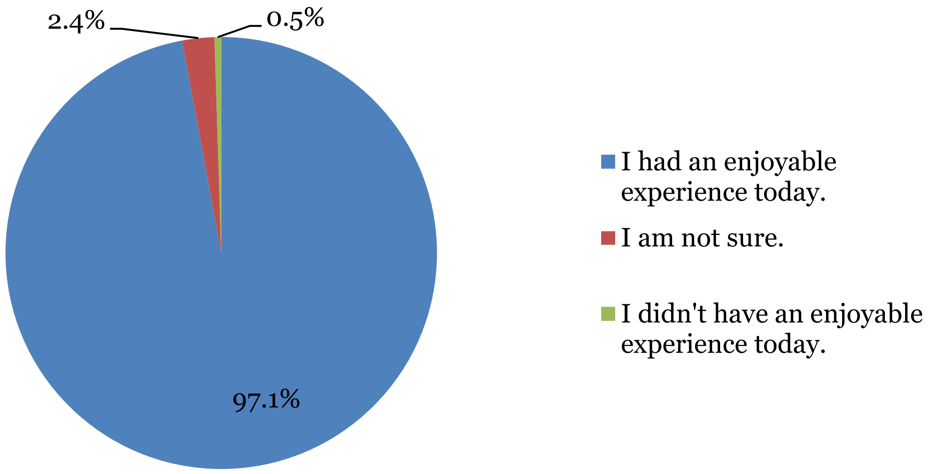

FIGURE 4. 76. Visitors' opinions on their experience

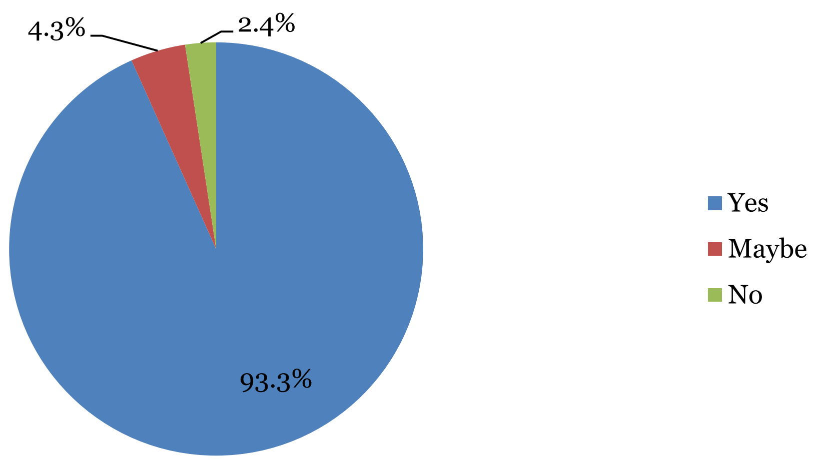

FIGURE 4. 77. Would you like to come back

In terms of the acceptability to the end-users, in this case, visitors, 78% of them indicated that they felt rather relaxed and calm during the visit, 97% of them said they had an enjoyable experience inside Exxopolis, and over 93% of the visitors would like to see the luminarium again and would recommend it to family and friends (Figure 4.75. – Figure 4.77.). One of the main reasons for visitors not feeling relaxed was that "There were too many children running around."[66] Another visitor criticised Exxopolis by saying that "You should make the sides stronger so you can rest on them and have a section for calmness and a section for running, and have it bigger and more variety of colours."[67]

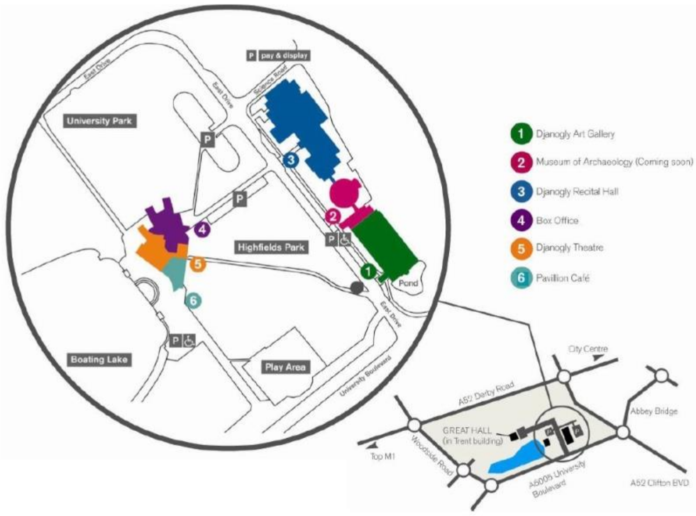

FIGURE 4. 78. Lakeside Arts Centre venue[68]

In terms of the appropriateness of the building site, Exxopolis was constructed on Highfields Park in front of the Lakeside Arts Centre. There are two free car parks outside the Lakeside DH Lawrence Pavilion for visitors to the Arts Centre and Park.

[66] See Appendix D.
[67] See Appendix D.
[68] Lakeside Arts Centre, "Lakeside Venues," ed. Lakeside Arts Centre – Location & Directions (2012).

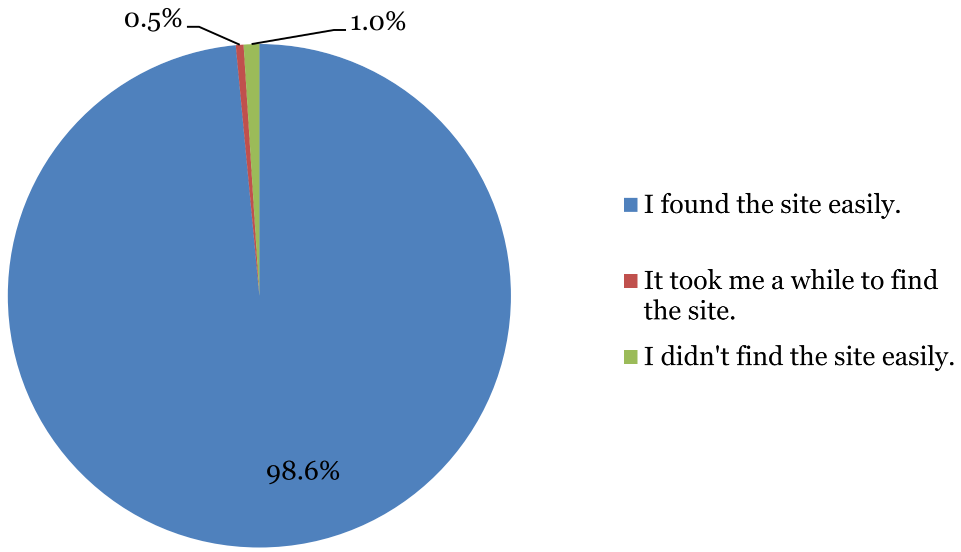

FIGURE 4. 79. Did you find the festival site easily

A regular bus service is available outside the Arts Centre, and nearly 99% of the visitors found the site easily (Figure 4.79.). Many visitors said they did not know about the Exxopolis exhibition until they saw it from the road in their cars. One visitor wrote: "I visited the Luminarium in 2005 in Budapest [Amozozo] and I didn't know about the Exxopolis this year. I saw it when we came for the theatre."[69] It could be argued that Exxopolis performed as a city landmark and attracted potential visitors to both the structure and the Arts Centre. It also enhanced the visitors' perception of the surrounding environment by providing a temporary, fun, and wondrous space that engaged the broadest spectrum of the public.

4.3.5 Contributions

The Architects of Air team contributes to both architectural design and social aspects. With regards to the design, the team has an international reputation for designing and handcrafting inflatable structures for public exhibitions. It is the only company in the world that has been producing this unique type of architecture for two decades. A luminarium lasts for around 300 days of exhibition over four years before it is cut into pieces to be recycled, and Parkinson claims that his company does not sell their structures. The design team is open with their information and resources and are also interested in collaborating with educational organisations in the future.

[69] See Appendix D.

Focusing on the social considerations, the Arts Centre crew and the local community groups in Nottingham joined the Windows Projects workshops to make the intricate windows of the Exxopolis Cupola. This shows that the structures can be made by people without professional training in arts or architecture. Furthermore, one of the strongest contributions of Architects of Air projects is that they raise enthusiastic communication between social communities and enable the members of the communities to learn new skills and knowledge.

FIGURE 4. 80. - FIGURE 4. 81. Windows Projects workshop; Workshop teams handcraft the "windows"[70]

However, it is not clear from this research whether the disabled visitors perceived the environment in the same way as other visitors because the design features for disabled people has not been thoroughly examined. From the number of disabled visitors that came to see Exxopolis in the company of family, friends or carers, it can be assessed that Architects of Air provides a friendly environment for the broadest spectrum of the general public. Capability's Anton Ogilvy Service in Dundee particularly praised the accessibility of luminaria when the structure Mirazozo was exhibited during the Edinburgh Festival in 2011. Capability reported that the structure can be enjoyed by people of all age groups, regardless of whether they have a disability.[71]

A recent BBC programme, *Inside Out East Midlands*,[72] reported from Nottingham that the luminarium has a potential to be used within art therapy for severely disabled children with cerebral palsy and other communication difficulties. Oakfield School and Sports College in Nottingham has used a structure made by Architects of Air inside the school building for therapy training sessions. Parents and teachers

[70] AoA, "Exxopolis," (2012).
[71] Capability, "Luminarium Gets the Thumbs Up For Access!," http://www.capability-scotland.org.uk/news-events/latest-news/luminarium-gets-the-thumbs-up-for-access!/ (assessed 12 December 2012).
[72] This was first broadcast on 26 November 2012 and was available on BBC iPlayer until 3 December 2012.

noticed a subtle improvement in the pupils, and they believe that it could have been a result of the inflatable structure. One of the parents, Jade Hisham, said, “It allows children to express themselves in a way that is normal to them. Not necessarily normal to outside society.”[73] Presenter, Marie Ashby, said “It does seem like it is having an impact on children. Now the school is working with Nottingham Trent University on a research project to find out why and if the inflatable structure itself is provoking certain responses.” [74] Architects of Air has achieved success in impacting on the broadest audience by providing maximum accessibility for the general public. Although it is as yet unknown whether it is the inflatable structure or the strong contrasting colours that have had a positive impact on disabled visitors, this could make a significant contribution in the related research field.

FIGURE 4. 82. A training session for disabled children inside an Architects of Air structure[75]

4.3.6 Limitations

The first limitation can be seen from the function that the structure provides. In consideration of the structure’s safety issues, the activities that can be hosted inside luminarium are limited in small performances and visitors walking around. There is a lack of further investigations in developing potential functions for different user groups.

Another limitation can be seen from the perspective of publicity and marketing. For instance, a visitor commented that, “My son from Northampton told me about this;

[73] "Insde Out East Midlands," ed. Tony Roe (BBC One 2012).
[74] Ibid.
[75] Ibid.

it was not in the Nottingham Evening Post [local news]."[76] It can be argued that many potential visitors, who regularly read local news online or in newspapers, were not accessed because the news about the exhibition was not widely advertised.

A key limitation can also be seen in the project management process. During a conversation, Parkinson was asked how the designer, also acting as the director, foresees the company's future over the next five to ten years. Parkinson explained that, because he lives in Gex, France, and he is not in the studio most of the time during the year and he is, therefore, sometimes not informed about progress in the UK. Currently, he is interested in learning more sophisticated computer software modelling skills, in order to transfer his designs more accurately to reality.[77]

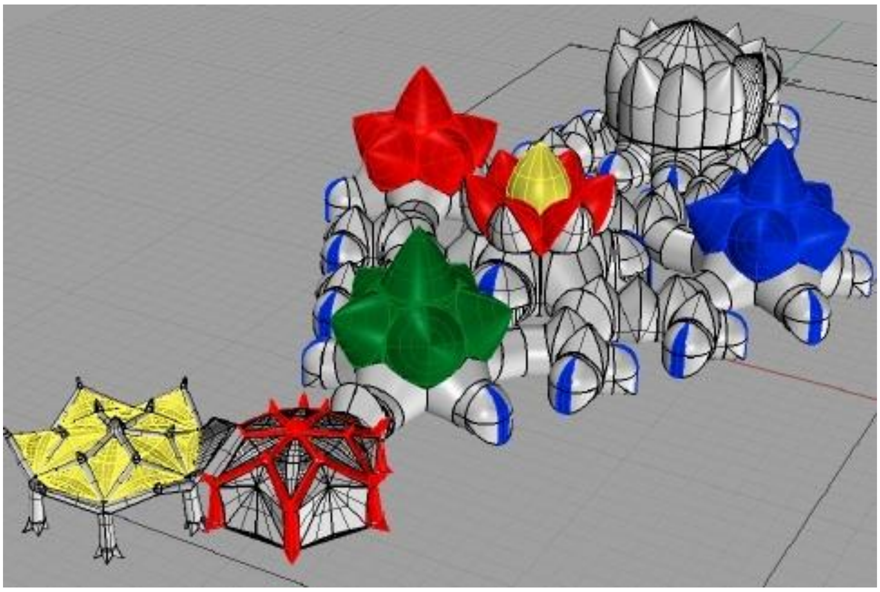

FIGURE 4. 83. A 3D modelling image of Exxopolis[78]

4.3.7 Recommendations

From observations on site, it was noted that a baseball was put on top of each metal peg to protect the PVC plastic from any potential scratch damage. One of the members of staff, whose main task was during the construction process, said that she once injured her knee on a metal peg that she could not see clearly in the dark when checking the structure after it was deflated.[79] Fluorescent tape could be used

[76] See Appendix D.
[77] Parkinson.
[78] AoA, "Exxopolis.".
[79] AoA Staff, in discussion with the author, 2012.

to cover the baseball so that they could be seen clearly in the dark. Furthermore, when the structure was deflated, the pegs would stay in the same location so that, with the help of the illuminated tape, the general shape of the structure could still be seen in the dark when people walked or drove past. This could encourage the curiosity of potential visitors and promote the design even when it is closed in the evenings.

FIGURE 4. 84. A baseball is used on the metal peg to protect the structure

The author noted that during some exhibitions, signs are put outside the structure to remind visitors that the luminarium is not a bouncy castle and that children are not allowed to jump on the structure. This limits the enjoyment of the design as young visitors may find it a more exciting experience if they could interacting with it through jumping and running. Parkinson explains that his objectives for the design are to create a relaxing atmosphere for all visitors, instead of aiming it only at a particular group of people.[80] Although the designs of Architects of Air have been developed significantly over the last 20 years, especially in the techniques of manufacturing much larger inflatable structures, the purposes of the designs have not been developed towards alternative creative approaches.

Parkinson completed the designer questionnaire on 27 November 2012. He selected *disagree* on two performance indicators, namely *thermal comfort quality is appropriate for its use* and *artificial lighting levels in the structure are satisfactory*. Apart from these, he agreed or strongly agreed with the majority of the indicators. Based on the outcomes of the user questionnaires and field research, the author ranked the indicators from the users' perspective and compared the results with the designer's opinions. The results are similar; however, the visitors showed more positive opinions towards the artificial lighting and considerations of circulation space.

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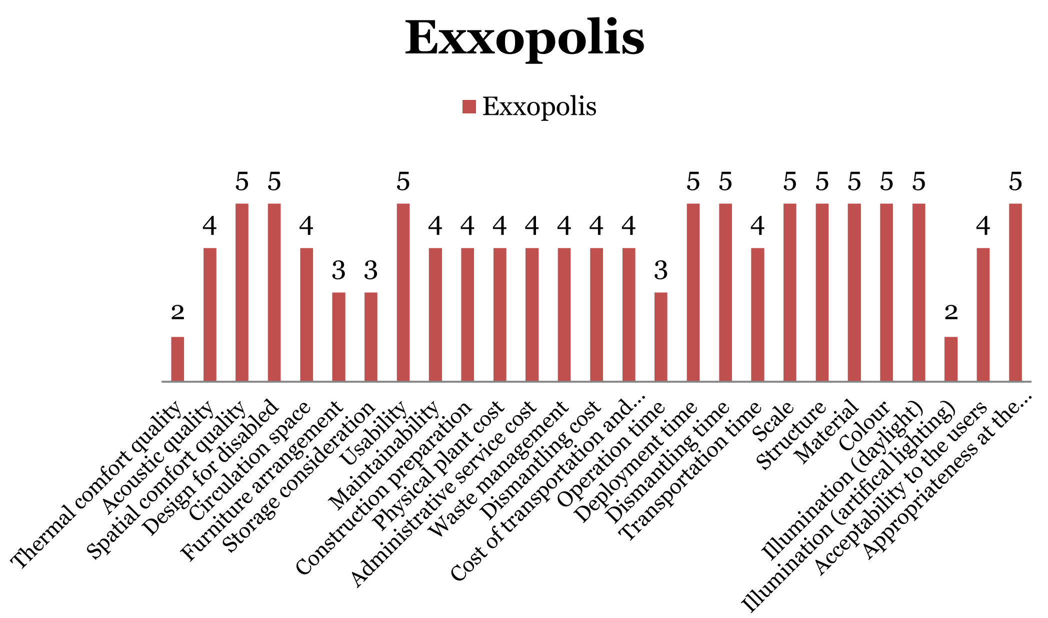
[80] Parkinson.

TABLE 4.4. Post-Occupancy Evaluation of Exxopolis – A Conceptual Model

A. General Information

Project name	Exxopolis
Client	Lakeside Arts Centre
Designer:	Architects of Air – Alan Parkinson
Function	Outdoor exhibition, musical events, performances
Type of architecture	Functional structure
Location	Nottingham, UK
Date of implementation	1–10 June 2012

B. Weighted Section Scores (ranked by Alan Parkinson)

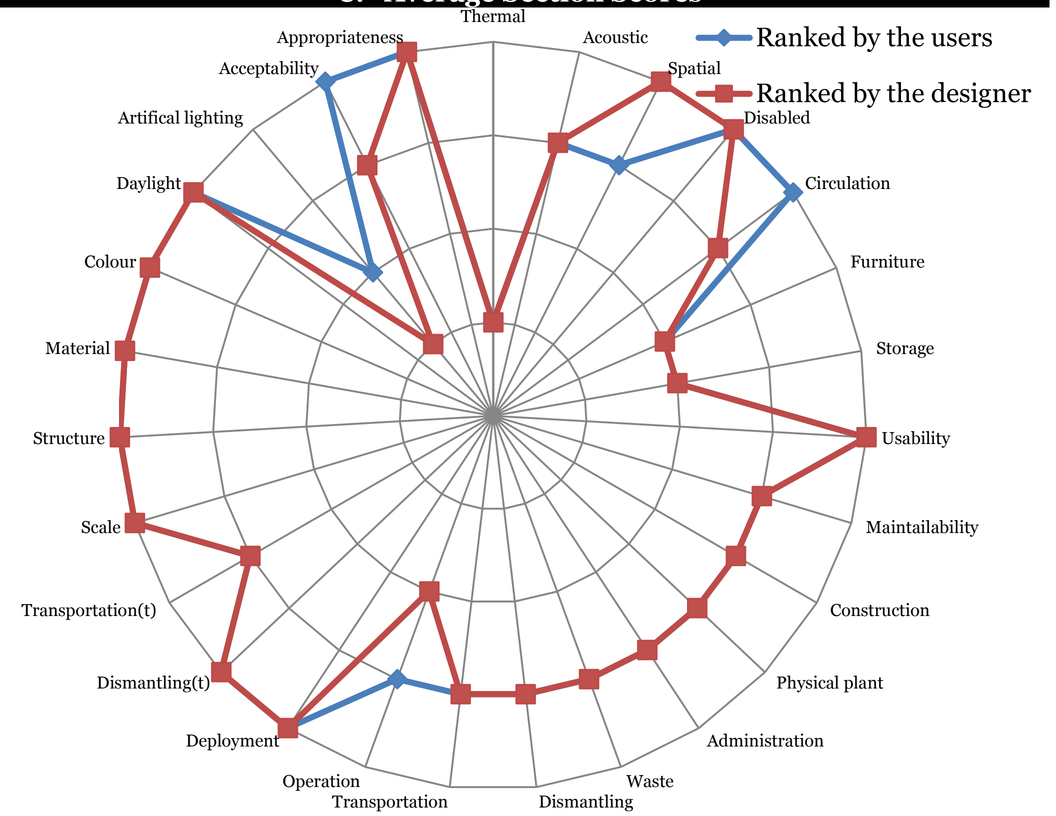


$$DQIdesigner = \frac{Function+Finance+Timscale+Aesthetics}{27\times 5} = 0.83$$

$$DQIuser = \frac{Function+Finance+Timscale+Aesthetics}{27\times 5} = 0.85$$

Both results 0.83 > 0.60 and 0.85 > 0.60 indicate that Exxopolis is a successful demountable structure project.

C. Average Section Scores

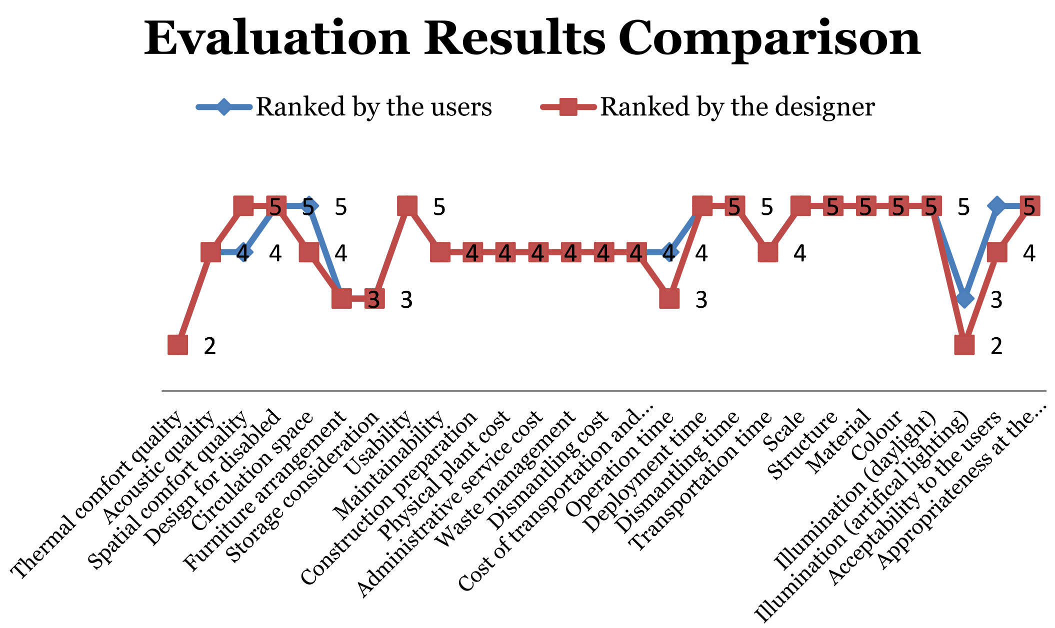


D. Opinions from users (Likes/Dislikes)

Likes	Dislikes
Colour	Floor
Light	Inside temperature
Shape	Ticket price (adults and children are the same price)
Location	
Sound environment	

E. Evaluation Results Comparison

The visualisation below compares the evaluation results of project value weighting.
The structure passed on 22 (81.4%) of the 27 factors marked as fundamental for this project.



F. Key Interpretations & Next Steps

Contributions:

- It is the only company in the world that has been producing this unique type of architecture for two decades.
- Architects of Air projects raise enthusiastic communication among social communities and encourage the members of the community to learn new skills and knowledge.
- It has been proven by other organisations that Architects of Air provides a friendly environment for the broadest spectrum of the general public.
- There is the potential possibility that the designs of Architects of Air have a positive impact on disabled visitors and they could make a significant contribution to the related research field.

Limitations:

- There is a lack of sophistication in using computer software in the design process.
- There is a lack of creativity in designing new inflatable structures.

Recommendations:

- The future designs could encourage more creativity and new forms of inflatable structure in order to satisfy users of different age groups.
- Further designs could be considered with a view towards offering an even more comfortable environment for visitors in terms of improving quality of thermal comfort.

Next Steps:

- Liaise with the designer and identify further information about the research project at Nottingham Trent University, which was presented in the BBC programme, regarding how inflatable structures and the bright colours could have helped to improve the learning ability of disabled children.

4.4 Kreod

The Kreod DIY Summer Pavilion, previously known as d_pod, is a demountable structure located in the Greenwich Peninsula, London, next to the O2 Arena. Chunqing Li is the designer and project director of Kreod, and he is a self-employed designer who has recently registered a company in the UK – Li Investment. Li was born in 1982 in Shenyang, China, and came to study in the UK in November 1999. Before he was awarded a BA (Hons) in Architecture from Liverpool John Moores University in July 2010, Li worked in a number of architecture companies, including Snow Architects in Liverpool (2005), Static Models (2005–2007), and Foster and Partners (2007). After obtaining his degree, he worked as an architectural designer at Leslie Jones Architects until March 2012, at which point he decided to concentrate on the pavilion full time.

The Pavilion Architecture was discovered through a search on Facebook[81] in January 2010, using the term *portable architecture* and Li's project, described as "a sustainable, ecological, portable, demountable and multi-functional temporary indoor or outdoor exhibition space",[82] emerged. An interview was arranged on 12 February 2010 to discuss the design concept and working ethics behind the project. A presentation was delivered by Li to introduce his design on 11 March 2010 in Milkandsugar, the RIBA Hub in the North West until its closure in April 2011. During the presentation, Li discussed the design concept of d_pod and introduced the computer software that he used in modelling. He stated that the design started from his exploration in parametric design, in which he was particularly interested and his model was first exhibited in Milkandsugar and later at the Do It Yourself Integrated City exhibition,[83] organised by the Liverpool Architectural Society on 28 October 2010. Li claimed during the presentation that his project was going to be built that year at Chavasse Park, Liverpool ONE and the elegant model appeared to attract the audience's attention. However, many questions were raised regarding how the complex structure would be built and who would be funding the project. On 15 June 2010, the author arranged to meet with Li to discuss his following approaches towards the success of d_pod. For many reasons, including funding and timing, d_pod was not built as expected. Li moved to London from Liverpool in late 2010 and started working for Leslie Jones Architects whilst continuing to develop

[81] Facebook is a social networking service launched in 2004 and founded by Mark Zuckerberg with his roommates and fellow Harvard University students.

[82] Li, "Design & Access Statement".

[83] The opening of DIY City was announced in Liverpool by Ruth Reed, president of RIBA. The exhibition was led by the Liverpool Architectural Society that brought together 24 exhibits representing communities and localities from across the Liverpool city region on both sides of the River Mersey.

his project and seek funding and partners. In an email to the author on 1 Septembers 2010, Li wrote: “Unfortunately, the pavilion project has been postponed; it will not be built this summer because of the current economy and the new policies by the new government. I am still working on the [d_pod], I have changed the design slightly. I will try to build it in London next year.”[84]

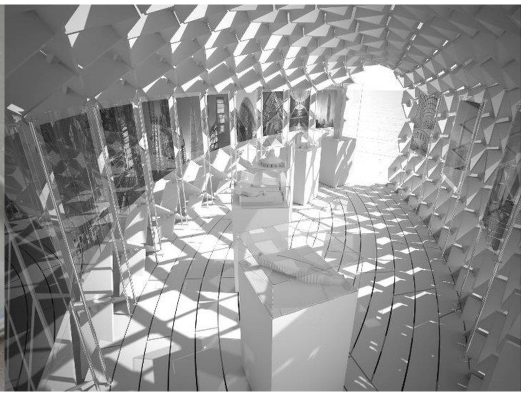



FIGURE 4. 85. - FIGURE 4. 86. The architectural model of d_pod (Kreod); A conceptual image of inside the structure[85]

At the beginning of 2012, the author was notified that Li obtained solid support from various partners, including Kebony, a Norwegian company that produces environmentally friendly hardwoods as a construction material, and agreed to supply the timbers. Vienna-based company Evolute GmbH and engineering expert Ramboll’s UK office also agreed to support and advise on the structural testing and fabrication process. Two following interviews were arranged with Li on 10 February 2012 in Liverpool and on 27 April 2012 in London, in order to obtain the most up-to-date information about the project’s development plans.

[84] Chunqing Li, Email, September 2010.
[85] ———, (2010).

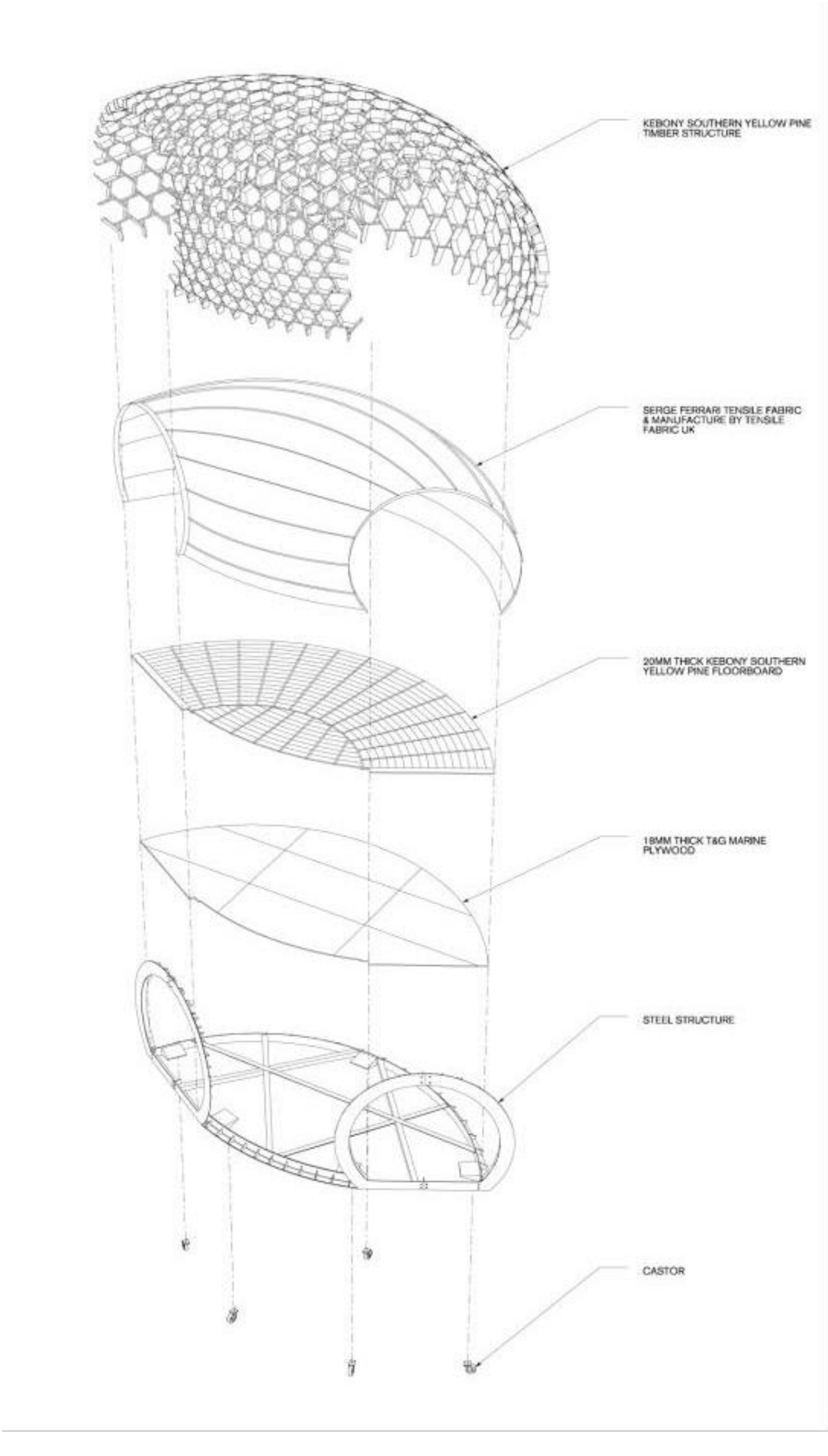


FIGURE 4.87. The design details of Kreod[86]

[86] ———, "Kreod Pavilion - Exploded Drawing," ed. Challenging Uncertainty & Impossibility Kreod (2012).

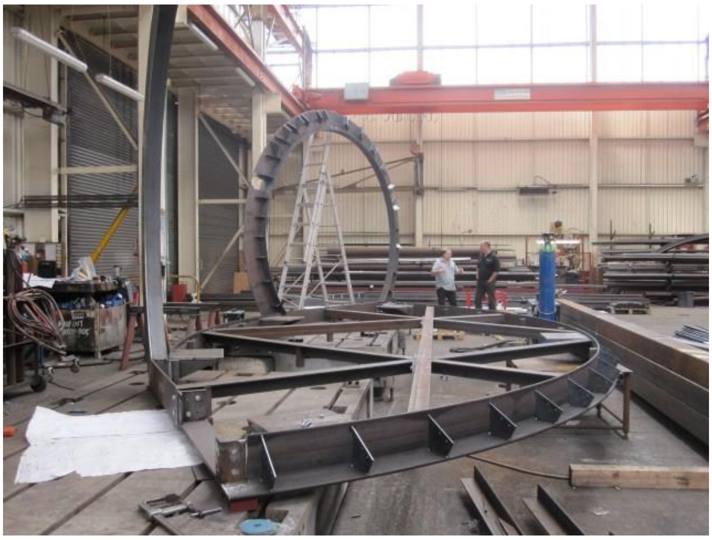


FIGURE 4. 88. The steel foundation being fabricated in Nottingham[87]

The author visited CNC Robotics[88] in Liverpool on 22 May 2012 to observe the timber fabrication process. All the timbers had been transported from Norway to the Liverpool Scenic Workshop for fabrication. The workshop used a CNC robotic arm machine to cut and carve each wooden component, 3,000 in total. A consistent error was noticed at the cutting edge of each component which was not symmetrical in profile. After a few more components were tested by the robotic arm, studio manger Jason Barker[89] and engineer Harri Lewis[90] believed that the error was due to the clamp that was used to hold the components was being slightly shifted by the vibration caused from drilling. Barker expressed concern that only one component could be completed before the end of July 2012.

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[87] Ibid.

[88] CNC Robotics is part of the company Liverpool Scenic Workshop Limited.

[89] Jason Barker is the managing director of Liverpool Scenic Workshop Limited – a company based in Liverpool, which specialises in the construction and installation of stages, scenery, backdrops and other associated scenic products.

[90] Harri Lewis holds an MPhil in Digital Architectonics and a MEng in Civil and Structural engineering. He has developed a number of interactive applications to help designers create elegant forms with embedded structural logic. He contributed to Kreod with structural modelling and analysis, connection design and physical testing.


FIGURE 4. 89. - FIGURE 4.90. The CNC Robotics arm; Wooden components ready to be used in construction

The steel foundations were transported from Nottingham to London and the first parts of timber components were transported from Liverpool to London in May 2012. A visit was arranged on 19 June to AR18 Company, London, to observe the construction process and meet the team. During the visit, the author discovered that the team was constructing the components from two sides simultaneously with the final parts meeting at the top of the structure, based on the way it was designed.


FIGURE 4. 91. - FIGURE 4. 92. The first component being constructed; The wooden components

In August, all construction materials and tools had been transported from AR18 to the final site, private land owned by Greenwich Peninsula Regeneration Limited.[91] The final construction took less than one month, with a team of six to seven people on site every day from morning until evening. After the first component was complete, the other two structures were erected quickly with solid experience gained

[91] Greenwich Peninsula Regeneration Limited (GPRL) is a joint venture between Quintain Estates and Development PLC and Knight Dragon. More information can be accessed at http://www.greenwichpeninsula.co.uk/.

from the previous months. Some small problems occurred at this stage, such as the metal joints that were used to hold the membrane sheet being fabricated in a bigger size than they should have been. There was not enough time to make these joints again, and it could have caused extra costs so the solution was to use hammers to modify the edge of each joint to the correct size.

 

FIGURE 4. 93. - FIGURE 4.94. The second component being constructed; The third component being constructed[92]

Kreod was launched on 18 September 2012, and the final design consists of three compartments for the different types of exhibitions and activities. The structure has a footprint of $60m^2$ ($3\times20m^2$), and 3m high. The exhibition space can accommodate approximately 114 A1 presentation panels, and 15 plinth-based displays (500×500×900mm). The pavilion can also function as a formal presentation space for up to 66 seated people, an informal gathering or a party. Kreod sits on castors and, therefore, no trench or foundation is required, which allows the structure to be moved and rearranged into different forms and spaces during the day or night. The pavilion can be located indoors or outdoors, providing maximum security especially when the three elements are pushed together to recreate an organic form. Li said at the opening event that: “It (Kreod) promotes architecture, culture and business in multiple locations within the city of London, and acts as a positive exercise for all of those involved.”[93]

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[92] Li.
[93] ———, Speech, September 2012.

FIGURE 4. 95. Kreod at the opening ceremony

4.4.1 Function

FIGURE 4. 96. - FIGURE 4. 97. Three components can be arranged differently; An inside view[94]

Based on the conversations with Li, Kreod was designed to address the design opportunities in respect of the local economy, providing competitive solutions, both aesthetically and economically. Ideally, it will be used by organisations interested in promoting their products through small-scale exhibitions and parties and, for example, Kreod is, at the time of writing, being used to advertise the business partners that supplied the site and materials. It is also used as a meeting place for Li to promote more business opportunities with potential partners. It is open to the general public and whilst anyone can visit during the daytime, there have been few public visitors since the design was launched because the project completion date was delayed until after the Olympic Games.

94 Ed Kingsford, "Kreod," (2012).

Each component can be pushed by five to six people and, in the evenings, the three components are arranged into a doughnut shape – the entrances at each side of the components are connected and form a completely closed shape. After locks are easily placed at the edge of the steel foundation, the structure, exhibition boards and any furniture are well-protected on-site.

4.4.2 Finance

At the same time as being the designer, Li is also the owner of the design and the structure. His sponsors include Greenwich Peninsula, AR18, Kebony, Ramboll, Evolute and HP. In return to the business partners that offered the site, construction materials and computer software packages, Kreod is being used firstly to advertise the products of the sponsor companies. Aside from the sponsors' support, Li self-funded the rest of the project. The project was built by enthusiastic volunteer students and no fee was involved. The architecture students were offered an opportunity to practise their architectural training skills. The design method and the technology that Li used allowed the team to see how many materials they were going to use and how much waste material would occur. They added the longest dimension on each component's file name – for example, for component 777, the name of the file would be M0777-329, where M means member, 0777 is the component number and 329 means that the longest length of the component is 329mm. The fabricator added 40mm extra (20mm on each end) for fabrication. This way, they minimised waste and fabrication was cost-effective and environmentally friendly.

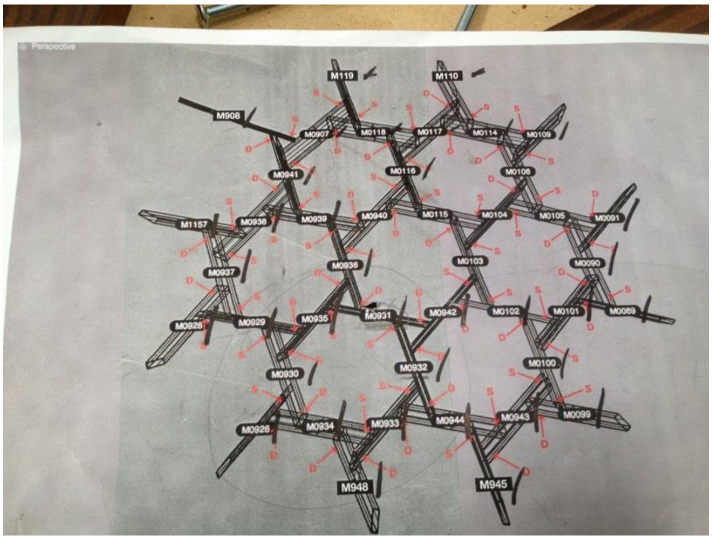

FIGURE 4. 98. Design instruction

4.4.3 Timescale

It took less than three years from the design concept first being proposed by Li as a graduation project, until the project was built and open to the public. The final construction stage started at the end of June and lasted until the beginning of September. However, the project was delayed for opening by two months, as it had been expected to launch at a similar time to the Thames cable car from the Greenwich Peninsula, to attract more visitors. The main cause of the two-month delay was that the CNC Robotics workshop did not manufacture the wooden components on time as planned. The workshop director explained that this was for two reasons: they had to wait for the delivery of a brand new CNC robotic machine before the prefabrications started, and a consistent error was identified on each component and they were not able to find out the exact reason.

4.4.4 Aesthetics

All the wooden components were supplied by Kebony from Norway. The beautiful Norwegian Southern Yellow Pine is a sustainable and durable alternative hardwood, which creates an organic exhibition environment that is warm and close to nature. The colour is dark brown, and it acquires a silver-grey patina over time if left untreated.[95] The author noted during site visits that Kreod has a natural wooden smell, which has enhanced its appearance to visitors. The membrane sheet was supplied by TensileFabric – a company based in Bristol, UK that designs and manufactures tensile fabric structures for both indoors and outdoors. The white plastic surface has been attached from inside the structure to protect the exhibition from rain and heat. The shadow of the wooden components reflects on the membrane sheet, moving with the direction of the sun and creating a cinematic image.

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[95] Li, "Design & Access Statement".

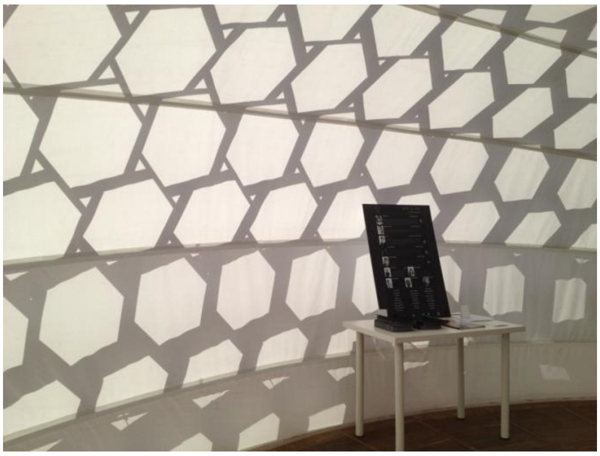


FIGURE 4. 99. The shadows on the membrane sheet

4.4.5 Contributions

The most important contribution of Kreod is that the parametric design method has been successfully applied to a demountable building. The parametric generation of the components was programmed in RhinoScript, a bespoke programming language used by the well-known CAD platform Rhinoceros. As part of the design team, Evolute was responsible for rationalising Kreod's complex input surface, designing the panel layout and the parametric detailing of the wooden members, and outputting the production geometry for fabrication. Kreod's design and manufacturing constraints were updated dynamically based on available resources. Li adopted simple manufacturing and wooden planks as building materials, avoiding complex CNC milling. The initial panel and beam layout provided by Li asked for complex, uniquely fabricated nodes in order to take the load of the structure, raising the fabrication costs significantly. Looking at the principal curvature lines allowed the team to understand how they could achieve a torsion-free structure with simple joint assembly that would lower the manufacturing costs. A breakthrough in the design of Kreod was led by the Ramboll engineering team when designing a reciprocal connection detail strong enough to take the load of the structure, while of ensuring elegance and simplicity at the same time. Evolute coded the generation of the member layout in accordance with the aesthetic and manufacturing constraints based on the detailed design.

Another contribution of Kreod is that it has been developed from a student's graduate design to a built project within three years. It has encouraged education in architecture by offering working opportunities for graduates and students to practise their construction skills and improve their understanding of architecture design. Moreover, it has united a group of passionate volunteer students to work as a team and achieve a shared success. Including Chunqing Li, the Managing Director, and Kristina Mogilevec, the Financial Controller, the crew also included eight main team members: Kin Ho, Ipek Kasaroglu, Hafed Burgess, Will York, James Green, Jan Balbaligo, Sushanon Go and Jing Cao. A total number of 24 volunteer students also joined at different times during the construction process and other than Cao, who is a medical student, all the crew members were architecture students at either RIBA Part I or Part II level.

Finally, the Kreod project demonstrates, as assumed in Chapter 2, that a small-scale completed demountable building can offer the satisfaction of producing a design that is all one's own. Because each small project can be unique, this is ideal for architects and promoters that want to stand out quickly when competing with others. Kreod has been featured by many media forms and magazines, including *DETAIL,*[96] Ecobuild[97] and ArchDaily[98] and it was honoured at the Surface Design Awards on 7 February 2013 in the the Temporary Structure Category. It can be argued that Li has been successful in promoting his design and has a great potential of setting up a small business in the architecture industry.

4.4.6 Limitations

A consistent error was noticed at the cutting edge of a large number of wooden components, and the error in each component caused a problem whereby they could not connect perfectly at the joints. The key feature of this design is that each structure should be formed naturally through the construction process because all the angles of the cuts are measured by computer software. This slight error could cause further problems as the last wooden component could not connect with the rest. An estimated 1,000 wooden components could not be used in the construction, and the majority of these were burnt as biomass for supplying hot water at the workshop in Liverpool. This raises the question of whether a design is only sustainable because the construction material itself can be reused or recycled.

[96] *DETAIL* is an internationally renowned journal magazine for architecture and construction details, produced by Detail publishers. It is published regularly in five different languages, including English, German, Spanish, Chinese and Japanese.

[97] Ecobuild is the world's largest event for promoting sustainable design, construction and built environments. The event includes exhibitor-strong product showcases, conferences and seminar sessions and interactive educational attractions.

[98] ArchDaily was founded in 2008 as the online source of continuous information for architectural news, including projects, products, events, interviews and competition information.

Although Li believes that all the wooden components can be reused for office or home furniture, the questions is whether there is a market that would be willing to buy them since they have been cut and had holes drilled in them. The final destination of Kreod is, as yet, unknown, because it has only been exhibited since September 2012, and further arrangements are still under discussion. Furthermore, Kreod raises the need to ask whether natural materials are the ideal option for parametric design construction. According to Barker, an important reason for all the edges not being perfectly cut is as a result of the natural patterns on the wood, and the darker the colour, the harder the wood. Therefore, when the machine cuts through the wood, the texture is different depending on the patterns of each individual wooden component. However, the construction of a parametric design project requires high accuracy in manufacturing skills because accumulative minor errors can cause further problems in the form of the structure.


FIGURE 4. 100. - FIGURE 4.101. The faulty wooden components were burnt for hot water; A few faulty components were designed as wall shelves[99]

4.4.7 Recommendations

This project raises an important question over whether natural materials are a good option for parametrically designed buildings and functional structures. The designer needs to consider good reasons for selecting construction materials and to do this, the designer needs inventive spatial and constructional concepts.

As previously discussed, a large number of wooden components could not be used and were burnt as an energy resource for hot water. Li was not aware of the problems of timber prefabrication until he visited the studio in May 2012, and prior to that, he had received images from Barker through email that suggested the prefabrication was going well. It was not until then that Li realised the project was

[99] Li.

going to be delayed for at least two months. It could be argued that, when Li was concentrating on seeking partnerships and sponsors, he ignored the importance of monitoring the project process and because the project was delayed until September, it missed the opportunity of attracting visitors who came to the site for the London 2012 Olympics Games. The designers of small-scale demountable builingds, who are often also the project managers, need to pay particular attention to the project monitoring because it is critical to ensure that a demountable building/structure project can meet its deadline.

During a conversation with the author on 6 December 2012, Li revealed that his initial intention of constructing the pavilion was to create a working methodology in architecture to prove the importance of practice in education. Moreover, he intends to succeed in his first step of entrepreneurship in the UK through this pavilion,[100] and further monitoring of Kreod is proposed in the future.

Li completed the designer questionnaire on 17 December 2012. He selected *agree* and *strongly agree* for the majority of the performance indicators. Regarding thermal comfort, storage, use-time, time for deployment and artificial lighting, he selected *neither agree nor disagree*. The main reason for this was that the structure is going to be in use until April 2013, and the artificial lighting was not installed. The newest plan is that Kreod is to be used as the press and visitor centre for Ecobuild exhibitions in London from 5–7 March 2013.

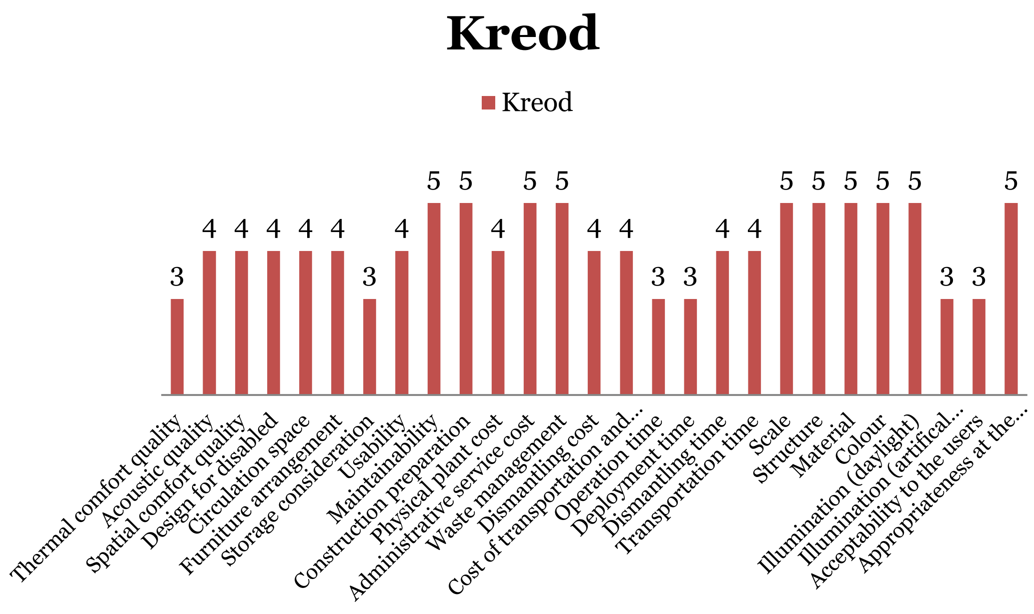
[100] Ibid.

TABLE 4.5. Post-Occupancy Evaluation of Kreod – A Conceptual Model

A. General Information

Project name	Kreod
Client	Li Investments
Designer	Chunqing Li
Function	Indoor or outdoor exhibitions, office meeting pod, garden feature
Type of architecture	Functional structure
Location	London, UK
Date of implementation	18/09/2012

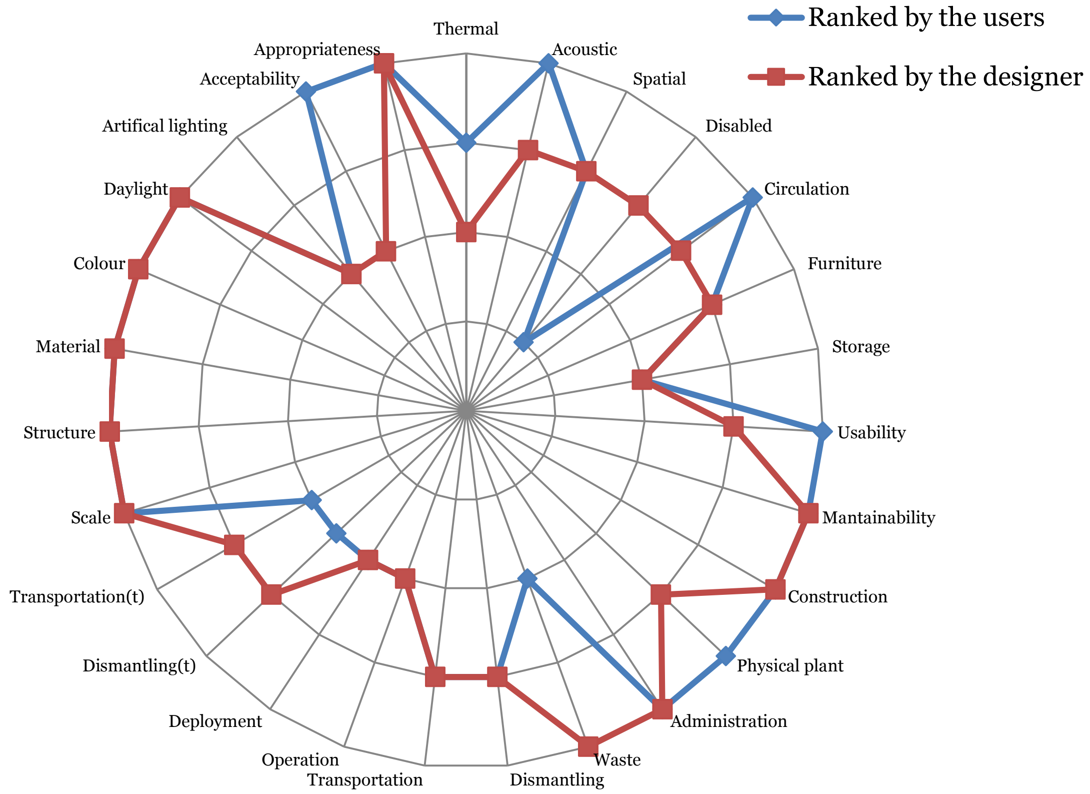
B. Weighted Section Scores (ranked by Chunqing Li)



$$\mathbf{DQI} = \frac{\text{Function+Finance+Timscale+Aesthetics}}{27\times5} = 0.83$$

The result 0.83 > 0.60 indicate that Kreod is a successful demountable structure project.

C. Average Section Scores

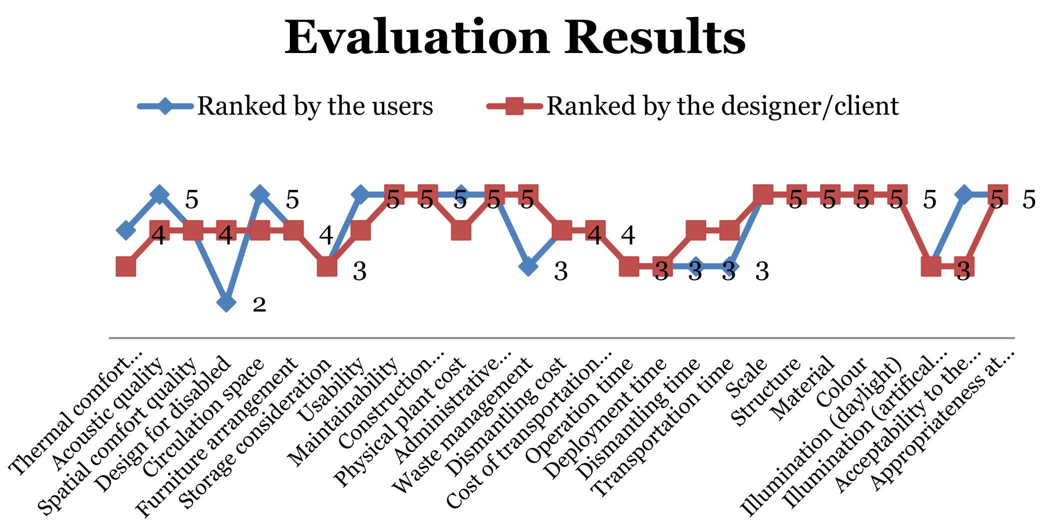


D. Opinions from users (Likes/Dislikes)

Likes	Dislikes
Colour	Construction delay
Material	LED lighting was not installed because of problems with the subcontractor
Smell of the material	
Appearance	

E. Evaluation Results

The visualisation below shows the evaluation results of project value weighting.
The structure passed on 21 (77.7%) of the 27 factors marked as fundamental for this project.



F. Key Interpretations & Next Steps

Contributions:

- A parametric design method has been successfully applied to this demountable structure.
- Advanced computer software was used in the design process.
- It has encouraged architecture education by offering working opportunities for graduates and students to practise their construction skills and improve their understanding of architecture design.
- The Kreod project is helping the designer as the client himself to promote his business profile in the creative industry.

Limitations:

- An estimated 1,000 wooden components could not be used in the construction, and the majority were burnt as biomass for supplying hot water at the workshop in Liverpool.
- The project was delayed for two months and missed the period of the London 2012 Olympic Games, which could have brought much more attention to the structure and the designer.

Recommendations:

- The designer needs to consider good reasons for selecting construction materials. To do this, the designer needs inventive spatial and constructional concepts.
- The designers could pay more close attention to the project monitoring process, because it is critical for the project manager to ensure that a demountable structure meets its deadline at the correct time.

Next Steps:

- Liaise with the designer regarding the future of Kreod.

Summary

TABLE 4.6. Case study comparison

Case Study Comparison

	Hualin School	Exxopolis	Kreod
Research methods	Interviews, questionnaires for users, volunteers and designer	Interviews, questionnaires for both the users and designer	Interviews, questionnaire for the main designer
Designers	Shigeru Ban Architects (Yasunori Harano)	Architects of Air (Alan Parkinson)	Pavilion Architecture (Chunqing Li), Ramboll (Harri Lewis, Jogn Harding, Stephen Melville), Evolute (Florin Isvoranu, Michael Elgensatz, Alexander Schiftner)
Client	Chengdu Hualin Elementary School	Various (Lakeside Arts Centre, June 2012)	Various
Owner	Chengdu Bureau of Education	Architects of Air	Li Investment
Date of implementation	August 2008	Various (started from 2012)	Various (started from September 2012)
Software used	Auto CAD	Rhino 3D	Auto CAD, Evolute
Architectural model	A 1:100 model was made before the construction	No model, but cardboard was used to test the design concept	A 1:100 model was made two years before the construction, and the actual structure was modified to ensure construction safety
Main function	Specific function – school building (non-commercial)	Multi-functional (commercial)	Multi-functional (commercial)
Location	Chengdu City, Sichuan Province, China	Various (the location that has been included in this research was in Nottingham, UK)	Various (currently limited to the UK, and the exhibition that has been included in this research is located in London, UK)
Scale and capacity	9.7×6×4.68m each classroom, up to 280 students and 6–8 teachers	50×20×10m (estimated), up to 70–80 visitors at the same time	3×2m², up to 66 visitors at the same time.
Type of architecture	Building	Inflatable structure	Flat-pack structure
Material	Paper tubes, plywood	PVC plastic	Wood, steel
Construction team	Volunteer students	Temporary labourers	Volunteer students
Contributions	• Provides a pleasant studying environment for 250 pupils and their teachers	• Provides a bright and friendly environment for visitors • Provides a friendly	• A success in applying a parametric design method

	• Increases the awareness of using sustainable construction materials in China • Supports architectural education by providing wide voluntary opportunities • Entirely demountable; the paper tubes and plywood can be recycled, the PVC windows and doors can be reused • The project creates very little construction waste	environment for disabled visitors • Engages the local community and encourages communication and skills learning • Encourages people's understanding of culture nationally and internationally • Valuable in the research relating to pneumatic structures	to demountable structures • Shows sophistication in using cutting edge modelling software • Encourages architectural education • A good example of setting up a small business in the architecture industry in the UK
Limitations	• Lack of funding management • Building lifespan unclear • Lack of communication between the designer and the school	• Lack of sophistication in using computer software • Lack of creativity in design	• Lack of consideration in selecting construction materials • Not convincing in claiming the project is sustainable
Recommendations	To encourage more solid communication	To encourage more design types	To consider good reasons for choosing materials

The above table provides a summary of each case study. This research has benefited from the selected case studies in various respects:

- The three case studies provide a series of evidence to support the claims made in Chapter 2 that small-scale, public use, demountable buildings can identify a specific need which it sets out to meet satisfactorily and efficiently. They are lightweight, flexible in function, require a small construction team and building site, and can be deployed and dismantled in a short time.

- The case studies show that demountable buildings can provide the same functional performance as transitional buildings. They can be made from much more sustainable construction material, such as paper, cardboard, wood, recyclable plastics and metals. A major benefit of using a demountable building is that it can be constructed and deployed rapidly without leaving heavy foundations.

- Both Exxopolis and Kreod prove that small-scale public demountable buildings can offer the satisfaction of producing something that is all one's own, and each project can be unique. Importantly, they can be used for the designers and project owners to promote their business in the creative industry.

- Case studies are used to examine the evaluation indicators, which are concluded from analysis and synthesis of an in-depth review of the design, use and operation of contemporary demountable buildings.

- They can be used to test the conceptual model designed by the author, to demonstrate how a small-scale public demountable building project can be evaluated holistically. In order to achieve a relatively objective evaluation result, evaluation questionnaire sheets were sent to each designer to rank the evaluation indicators. These evaluation indicators were ranked objectively for each case study, based on the data collected through site visits, questionnaires and interviews. The final stage concentrates on comparing the evaluation results between the designers and the author and the gaps are identified with further questions and recommendations.

5

Conclusions

The structure of this research consists of three parts: exploration; proposition; and testing. These are joined together by managing the research project through four steps: defining the research goals; ensuring a common understanding; building case studies; and reviewing progress. At the beginning of the project, the history and meaning of demountable buildings was outlined in broad terms, including related areas such as portable architecture, mobile architecture and temporary architecture. The literature review indicated that many terms have overlapping meanings, and it was essential that a more specific building type was identified before conducting a comprehensive study on its design, construction and operation. Following a broad-ranging review, an in-depth study of public-use demountable buildings was carried out, and although the research focusses on small-scale projects both large and medium-scale projects were also discussed and analysed. This is because many of these have been designed by architects and designers with world renowned reputations, and they are representative of the sector and largely successful.

Based on the information gathered, a set of criteria relating to the functional performance of demountable buildings was established, and following the creation of design quality indicators the key concepts and elementary principles of evaluation were explored. Subsequently, the existing evaluation and analysis methods were also reviewed and synthesised. With an advanced understanding of the process and implementation of evaluation, the positive and negative features of each method was clarified and having summarised what was learnt through appraising the suitability of these methods against their adaptability to demountable buildings, an Evaluation Conceptual Model was proposed, including twenty-seven design indicators that address the key attributes of the functional performance of demountable buildings. Three strategies were used to test the research findings and the Conceptual Model: case studies, international conferences and focus groups. Case studies were potentially valuable in creating three scenarios of how demountable buildings were examined.

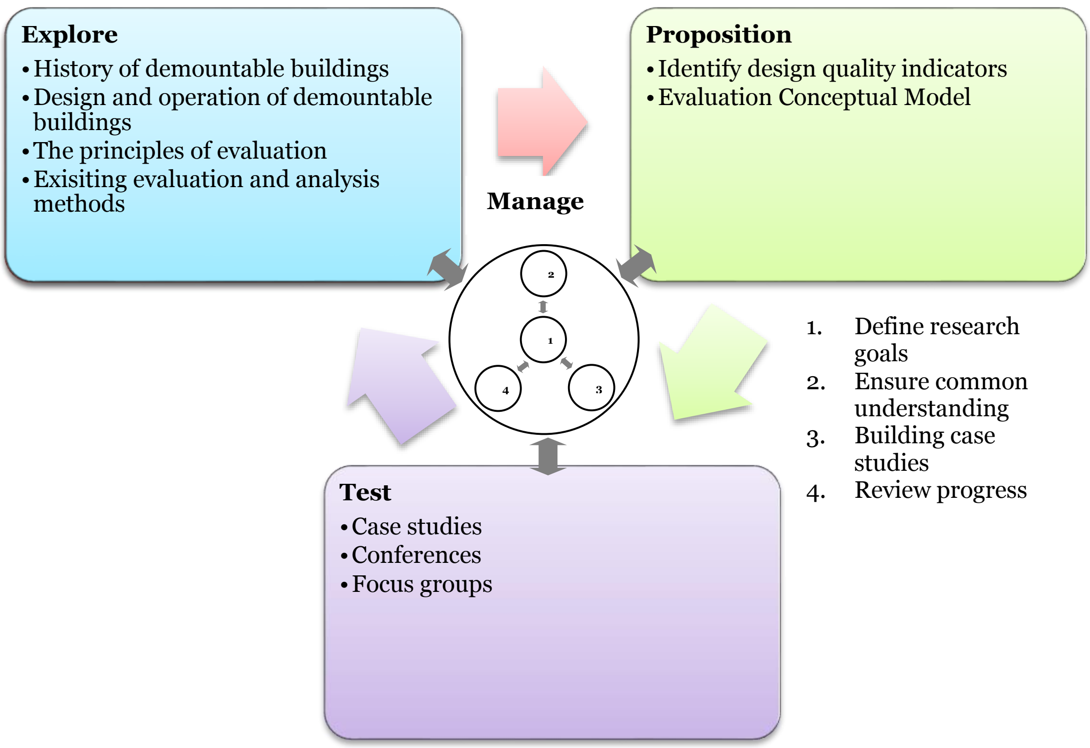


FIGURE 5.1. Research structure diagram

This ambition has become to make significant contributions to architects and designers' knowledge of demountable buildings, not only in terms of theoretical advances in relation to contemporary designs, but also in the techniques of transferring and combining knowledge from existing evaluation methods to the building industry. This chapter draws together the key research findings, and identifies the limitations, before proposing solutions through the discussion of future research direction.

5.1 Key Findings

This research makes three main contributions towards the understanding of demountable buildings. It provides an update in knowledge of contemporary demountable buildings in terms of design, use and construction. It also provides a synthesised review of the existing evaluation and analysis methods that can be adapted to demountable buildings. Finally, the research assumptions were examined through carefully selected case studies, and the findings were proven to be useful, practical and adaptable for further research in the related areas.

Finding I

With respect to the first contribution, the key factors in the design and operation of demountable buildings were investigated. These were analysed in terms of function, finance, timescale and aesthetics. Function can be assessed through suitability, reliability and flexibility, focusing on spatial comfort and usability. In demountable buildings, the building costs include construction materials, components, building machinery and tools, hiring of construction workers, design services, operation, transportation of building elements or components, renting or occupying the building site (indoor or outdoor), administrative services, and allocating waste building materials. Demountable buildings incur a further cost due to dismantling the building, and storing and transporting its components for future use. Timescale refers to the duration of the project, including design, construction, use by events operators and visitors, deployment and transportation. The entire life cycle of a demountable building has been analysed here within three scenarios:

(i) All building elements will be re-used.

(ii) A quantity of the building elements will be re-used.

(iii) All building elements will be recycled.

Aesthetics includes visual appearance, such as scale, construction system, material, colour and illumination), acceptability to the users and appropriateness at the building sites. Through a comprehensive analysis of the literature, small-scale projects were often transported whole instead of having to be dismantled for the next deployment. By doing this, not only does it save construction time, but it is also more convenient for users such as project owners and event organisers. Most medium-scale and small-scale demountable buildings are deployed in multiple locations, while most large-scale demountable buildings are deployed in a single location. The five major demountable building structural systems – module, flat pack, tensile, pneumatic and combined – give different building appearances. They all generally give an impression of “light-looking” in compared to static buildings. The five major materials used in demountable buildings are glass, concrete, wood, metal and plastic. In addition to these, paper, cardboard, bamboo, natural fibres and many other unusual materials can also be used in their construction. Importantly, the use of demountable buildings addresses the significance of public space and the fact that, without it, many demountable building constructions would not be possible. This suggests a new proposition for using demountable buildings as a method for exploring urban growth, such as their use in experimental projects to measure the scale of public space and its capacity, and explore its relationships with visitors. Research projects in this area can be conducted satisfactorily by arranging student design competitions and organising research workshops.

Finding II

The second key finding has been with regard to the role of evaluation in the life cycle of demountable buildings, as well as the evaluation principles and the evaluation process. It has been argued that evaluation can be seen as a part of the design process, and each design criterion may require knowledge of a specific area. The evaluation principles were discussed through answering four questions:

(i) What is the evaluation going to be used for?

(ii) Who conducts the evaluation?

(iii) How can the results of the individual evaluation criteria be integrated into a composite measure of criteria?

(iv) What happens after the evaluation?

The generic process of evaluation from pre-occupancy evaluation to monitoring and post-occupancy evaluation has been discussed with a specific focus on post-occupancy evaluation because the functional performance of a demountable building is best revealed after it opens to the public.

Following an in-depth discussion of the meaning of evaluation, the author presented a series of existing analysis and evaluation methods that have been successfully used in project assessment and management was presented. The guidelines developed by city council and cultural sectors are used to analyse projects qualitatively whereas the methods used in humanitarian response and cultural development tends to focus on high-resolution satellite imagery to collect quantitative data. Post-evaluation of the container temporary housing uses both quantitative surveys and qualitatively driven interviews, and all other methods, such as UNCHS (Habitat) Guidelines for the Evaluation of Post Disaster Programmes, EMMA, and Tearfund Shelter and Reconstructed Standards, are used to collect and analyse qualitative information. Other than ISO 14001:2004 which is used for qualitative assessment, all other environmental assessment methods are used to examine quantitative data, such as distance, sound, thermal measures and air quality environment. Although CASBEE for Temporary Construction states that it also examines qualitative aspects such as service performance, including functionality, reliability and cultural responsiveness, there is no evidence in the original document that suggests how the evaluation can be carried out. Furthermore, as the current CASBEE for Temporary Construction only exists as a Japanese version, there is a possibility that the Japanese Sustainable Building Consortium and Institute for Building Environment and Energy Conservation are still developing their guidance and evaluation methods for the future.

The lessons learnt from examining the existing methods include:

(i) Evaluation is often a subjective process, since evaluators may have differing opinions. The results can also differ depending on when the evaluation is carried out.

(ii) The evaluator should be precise in respect of the stage of evaluation – i.e. whether it is pre-occupancy evaluation, monitoring, or post-occupancy evaluation. The indicators differ depending on the evaluation purpose. For example, IES, DesignBuilder, LEED, BREEAM and other computer-based evaluation methods focus on pre-occupancy evaluation, while questionnaires and interview techniques are commonly used during the post-occupancy evaluation process. The methods claim that they can be used at any stage of an evaluation process and, as such, ASPIRE is only appropriate when it is used for creating uncomplicated reviews and analysis on a holistic scale.

(iii) Quantitative attributes, such as temperature, acoustics and lighting, and qualitative attributes, such as users' opinions regarding colour, space and a building's appearance, are often evaluated separately. A comprehensive evaluation method should contain both quantitative and qualitative data that addresses the functional performance of a demountable building as a whole. Qualitative data can be quantified by designing a ranking system.

(iv) A ranking system is often used in the analysis and evaluation process to compare the multi-attributes.

(v) A radar chart is often used as a graphical method to display multivariate data, results from ranking the attributes. Radar charts are a useful way to display multivariate observations with an arbitrary number of variables, although, they are not useful when comparing scores. In this case, a simple chart can be more helpful.

Having identified the key factors of demountable buildings and studied the existing evaluation methods, the results of the review suggested that a conceptual toolkit could be proposed to address how fragmented anecdotes were transformed into structured evidence, developing a conceptual model for the effective evaluation and evidencing of public interest initiatives. Among all the evaluation methods that were analysed, the Design Quality Indicator (DQI) was adapted and a new tool developed that is specifically used for the post-occupancy evaluation of small-scale, public, demountable buildings. Twenty-seven indicators were identified through the reviewing of previous research, including: thermal comfort quality; acoustic quality; spatial comfort quality; design for disabled users; circulation space; furniture arrangement; storage consideration; usability; maintainability (materials); maintainability (structure); construction preparation; physical plant; administrative service cost; cost of allocation; dismantling cost; cost for transportation and storage; use time; deployment time; transportation time; scale; structure; material; colour; illumination (daylight); illumination (artificial lighting); acceptability to the users and appropriateness at the building site.

The Evaluation Conceptual Model FFTA (function-finance-timescale-aesthetics), includes two parts: the FFTA questionnaire and the FFTA visualisation. The FFTA questionnaire is a coherent, straightforward, non-technical set of statements that collect the opinions from all stakeholders by looking at the function, finance, timescale and aesthetics of small-scale, public demountable buildings. The questionnaire includes two sheets: the evaluation indicator list and the details of the questionnaire. The purpose of the indicator list is to clarify the exact meaning of each indicator and provide a common definition for the evaluator before they fill in the questionnaire. The questionnaire is presented on a single sheet, with clear instructions provided, to allow the evaluators to treat uncertainty explicitly. For example, when Alan Parkinson, the director of Architects of Air, was asked about his opinion on the colour of the building, he was able to select a response from five alternatives in an order of hierarchy from low to high: *strongly disagree*, *disagree*, *neither agree nor disagree*, *agree* and *strongly agree*. The weighting system of FFTA was applied to indicate Parkinson's opinions. The results could be different, depending on how he judged the success of various aspects of his inflatable structure. The FFTA was graphically presented in various ways that highlighted comparisons between groups of respondents, comparing the views of the eventual building users with those of the delivery team. As such, each stakeholder was able to rank the indicators separately, and the results were generated together for further comparison. It could also be presented to compare a number of stages of the evaluation, and to present how these are being achieved through the modifications in design. For example, after a demountable building is evaluated and dismantled for further use, design changes are often made for fairly common reasons, such as the clients' needs, site requirements or because a part of the building needs to be replaced. When the building is used for the second time, the evaluation results can, therefore, be different. At this stage, the results can be presented as a series of scenarios, to demonstrate the changes and therefore propose further recommendations for the project.

Finding III

The final key finding relates to the comparative case studies of three projects that were explored in depth: Chengdu Hualin Elementary School, designed by Shigeru Ban Architects from Japan in 2008; Exxopolis, designed by Architects of Air, a company based in Nottingham, UK; and Kreod, a multi-functional structure designed by architect Chunqing Li which was exhibited after the London 2012 Olympic Games. For the purpose of researching the case studies, an unstructured interviewing strategy was employed to interview professional groups, including researchers, architects, designers, event organisers, construction organisers and volunteer students. The unstructured interviews were conversational and used to obtain qualitative information. A structured interviewing strategy was used in cooperation with the building users to obtain both quantitative and qualitative data. The structured interviews were specific, offering the interviewees a range of answers to select from, and were interpreted at a later stage.

These case studies were used as a research strategy to test the research hypothesis and draw conclusions objectively. They provided evidence to support the statement made in Chapter 2 that small-scale, public use, demountable buildings can identify a specific need and set out to meet it both satisfactorily and efficiently. They are lightweight, flexible in function, require a small construction team and building site, and can be deployed and dismantled in a short time. The case studies demonstrated that demountable buildings can provide the same functional performance as transitional buildings. They can be made from much more sustainable construction materials, such as paper, cardboard, wood, recyclable plastics and metals. A major benefit of using a demountable building is that it can be constructed and deployed rapidly without leaving heavy foundations.

Importantly, they can be used by the designers and project owners to promote their business in creative industries and above all, the case studies were used to examine the evaluation indicators that derived from the analysis and synthesis of an in-depth review of the design, use and operation of contemporary demountable buildings. They were used to test the FFTA Evaluation Conceptual Model to demonstrate how a small-scale public demountable building project can be evaluated holistically. In order to achieve a relatively objective evaluation the questionnaire was sent to each designer to rank each evaluation indicator. The author then ranked evaluation indicators for each case study objectively based on the data collected through site visits, questionnaires and interviews. The final stage concentrated on making a comparison between both sets of the evaluation results and the gaps were identified with further questions and recommendations.

Evidently, the evaluation methods for small-scale public demountable buildings can be varied and numerous. The selected methods need to reflect the architect or designer's design intention from a specific perspective. The Evaluation Conceptual Model for public demountable buildings can potentially be adapted to other types and scales of demountable buildings as part of future research. The key challenges, however, are that it is important for the stakeholders to decide who conducts the evaluation before identifying the precise evaluation indicators that are directly linked with the purpose of the evaluation and the key characteristics of this particular building type. Depending on the project's complexity and the importance of each criterion, the evaluator can be selected from different stakeholders. The client might be particularly interested in assessing function, finance and timescale during evaluation because they normally provide the project funding and communicate directly with the end-users. The designer might be particularly interested in assessing function and aesthetics during evaluation, because they design the building and are interested in the quality and appearance of the project. They are often also interested in finance due to the budgetary requirements of their client. Finally, an external evaluator, or consultant, might be interested in all aspects, although this depends on the priority of each evaluation criterion as established at the start.

5.2 Limitations and Further Research

A research project of this nature has several limitations based on the temporal and practical constraints of PhD-level research.

- This research examines the functional performance of demountable buildings, and concentrates on the quality of building services, such as functionality, usability and durability. Environmental performance, such as air quality, outdoor environment and energy consumption, is studied less thoroughly due to the technical requirements involved, such as specific computer software and other measurement equipment.

- The research concentrates on the post-occupancy evaluation of demountable buildings and, therefore pre-occupancy evaluation and monitoring are not examined and are analysed less. This is because the research goal focuses on the functional performance of a building which values the users' opinions and aims to improve communication between the designers and the users.

- Due to the research scope, although medium-scale and large-scale projects were reviewed to enable the design quality indicators for demountable buildings to be developed, they were not specifically assessed within this research. This is because they are much more complicated in terms of project management, and normally requires multiple designers, large construction teams and relatively more advanced technology. This was not possible within the scope of an individual PhD programme, since the complexity requires a longer research process and more funding.

- Other public-use buildings, such as demountable offices, clinics and theatres, were not specifically examined in this research, because there were no suitable case studies available for the author to use during the research period. Whilst the study of an elementary school focusses on a building with inherently different functions than a public exhibition space, the provision of a satisfactory evaluation conceptual model, which has the adaptability and flexibility to be applied to the assessment of other building or functional structure types, enables the research findings to represent a wide range of demountable buildings. Although each individual building clearly offers a different function, they can be assessed under a general framework for conceptual evaluation.

- The Evaluation Conceptual Model was sent to the designer of each case study to assess their design project for post-occupancy evaluation. Although feedback was received from the three designers within a sufficient time frame, the usability of this model, in terms of how convenient it was to participate in ranking the indicators, was not tested. Currently, the Evaluation Conceptual Model is limited in its theoretical recommendations, and although it provides a practical guide that has been tested through case studies, it is not yet able to broaden its use for a greater impact. The usability of the Evaluation Conceptual Model should also be considered within future research and many potential approaches could be further developed, such as the development of a practical computer-based tool or evaluation software which can be used by architects or designers for comprehensive evaluation. It could also be developed as a mobile device-based application for users who are interested in the design of demountable buildings.

- In this research, the evaluation of small-scale public demountable buildings focuses on the relationship between the building and its users. The relationship between the building and its surrounding environment, including the construction site and surrounding conventional buildings, is discussed in general and, whilst not examined against a set of criteria, the important indicators of how the built environment can interact with demountable buildings to create a better visiting/occupying experience are addressed.

Considerably, the limitations of this research are essential to developing future research projects. Four directions in which the research can be developed further, to provide a field for further investigations that are conceivable in different social and cultural settings are suggested below.

Direction 1 – Temporality and Territory

Demountable buildings and functional structures are normally designed to be deployed and re-assembled many times which, in essence, makes them a type of permanent building or structure. Their temporary existence as a fully functioning building or structure at each location raises an interesting question of the links between temporarily created space and territory. Helen Hamlyn Research Associates, in partnership with Steelcase [1] and IDEO, [2] discovered through research that a temporary environment could enhance team working. The project, *Places Please: A Temporary Environment to Enhance Team Working*, lasted for two years, from October 2001 to October 2003, and the team used six components including a portal, props trolley, tablet, chandelier, rollout set and rotator to create different scenarios. The aim was to develop a component-based system capable of temporarily transforming a space to enhance the collaborative experience and enable organisations to innovate more effectively.[3] At the end of this project, Places Please was able to provide a flexible framework for participants to create their own work settings and methods. Greg Epps states that "only a space, which is open to user interpretation and full of potential applications, can provide this opportunity to experiment and innovate".[4]

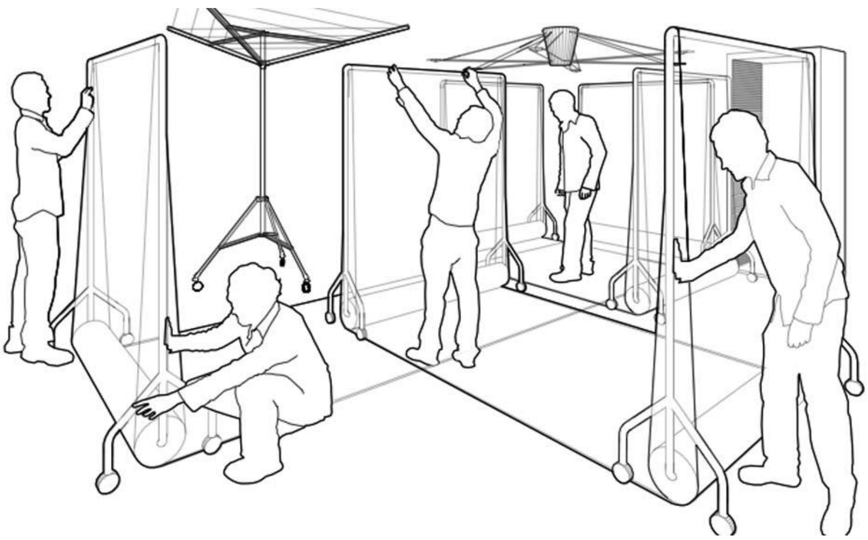


FIGURE 5.2. A sketch of changing the project space[5]

[1] Steelcase is a company founded in 1912 that provides innovative office furniture products worldwide. It has headquarters in Grand Rapids, Michigan, United States.
[2] IDEO is an international design and innovation consultancy founded in Palo Alto, California, United States. The company's areas of expertise include design products, digital experience, interactive design and project management and consultancy.
[3] Greg Epps, "Place Please: A Temporary Environment to Enhance Team Working,"(2003), http://www.hhc.rca.ac.uk/530-532/all/1/Places-Please.aspx (assessed 18 January 2013).
[4] Ibid.
[5] ———, "Changing the Project Space," (2003).

On a bigger scale, questions regarding the links between temporary architecture and territory can be identified. For example, in disaster-affected areas where the refugees inhabit temporary shelters, they also need privacy and personal space. The shelters are constructed not only to reduce their anxiety after the disasters but also to create a temporary community. This issue arises particularly during a period when transitional shelters, such as prefabricated houses, are used and the occupants start to rearrange their own spaces and belongings. The considerations of territory in disaster-affected areas go beyond shelter design, because they involve a much more complicated study of users' behaviours in a specific situation, i.e. when the fundamental needs are required in emergency circumstances.

On an even larger scale, what relevance does temporary architecture and urbanism have on territorial measurement, and can architects and urban designers capture the complexity of contemporary territories, whilst shaping their future configurations? What are the hypotheses and goals of such territorial designs of the future? Jean Gottmann states that "territory is a concept generated by people organizing space for their own aims".[6] Temporarily constructed architecture certainly creates ephemeral territory for its users, but how this helps to enhance people's quality of life is yet to be explored. The research in this area can be carried out by academic researchers, NGOs or organisations who are interested in territorial studies and improving people's living conditions.

Direction 2 – Research in Urban Studies

Another interesting argument raised in this research is that demountable buildings can be used as a tool to explore contemporary cities because they often require an open space with easy access. This emphasises the importance of public space in cities, an example of which is the Zócalo, the largest plaza in the centre of Mexico City which is the political hub for thousands of protestors, and the centre of cultural and artistic events including the Festival de México, city parades and performances. The Nomadic Museum, designed by Colombian architect Simón Vélez, was exhibited from 19 January to 27 April 2008 in the Zócalo.

[6] J. Gottmann, "The Evolution of the Concept of Territory," *Social Science Information Social Science Information* 14, no. 3 (1975): 29.

FIGURE 5. 3. - FIGURE 5. 4. An open air concert at the Zócalo;[7] The Nomadic Museum at the Zócalo[8]

City squares are often popular places for demountable buildings to be constructed. If the purpose of encouraging such a design is to add a creative and thoughtful layer to a public place, the challenge is to design a space that people will want to use and participate in, thus achieving its optimum functional performance. The real motivation for public-use demountable building designs is creating places that are "decided on by the occupants",[9] which means that the building has maximum freedom in its functionality and appearance. The satisfaction with its adaptability and flexibility will eventually lead to a sustainable, democratic future city, where those who live there contribute to designing their living environment. It should be noted that a user participating in the design process is different from a user leading the design. The latter situates the users as decision-makers, supported by professional architects and designers.

To achieve their full potential, however, the design and evaluation considerations of public-use demountable buildings needs to value identifying and analysing the users' real needs more centrally within the decision-making processes of public and private sectors. Furthermore, educational programmes in built environments and related fields, such as cultural organisation, need to promote more desire within the general public to be interested in, and not afraid of, becoming involved in the design process. Perhaps researchers from multidisciplinary backgrounds, such as civic design and urban design, could use demountable buildings as a research tool to map activities in cities, thus proving the value of transportable buildings on a bigger scale.

[7] Photolibrium, ed. Zócalo Square (2008).
[8] Gregory Colbert, "The Nomadic Museum - Mexico City," (2009).
[9] Friedman, Y. (2006). *Pro domo*. Barcelona, Actar.

Direction 3 – Translating Cultures

Research has revealed that a large amount of public moveable and transportable architecture is designed to tour worldwide, including the Nomadic Museum, Architects of Air projects and the Chanel Mobile Art Pavilion. The design objective for architecture to be able to be transported and used worldwide raises three important questions:

- How is public moveable architecture accepted by user groups with different cultural backgrounds and languages?

- How does public moveable architecture fit into different built environments and does the relationship between the architecture and the site enhance the visitors' experiences?

- How can we learn from visitors' responses towards the architecture in order to benefit project evaluation at a later stage?

These questions can be used to generate an analysis of the role and responsibility of moveable architecture in translating cultures in cities. The emerging need for understanding and communication across diverse cultures is strong, with a good example being the World Expo where all countries are able to express themselves and bring their culture to the world stage for a short time through a temporary building. Although it may be the events, exhibitions and performances that attract the visitors, without temporary spaces that are designed for translating culture, the events could not happen. In most situations, Expo buildings are demolished, dissembled, reused in part or returned to their home country, although many buildings are now transported to a new location near the Expo site and become a permanent building with minor modifications. In this context, moveable architecture becomes the ambassador of a particular culture, and is welcomed by the public in the broadest sense.

As Peter Bishop and Lesley Williams state, "temporary uses can challenge the dominant culture and the 'dominant frame of the city as an avenue for competition and exchange' and demonstrate new ways of building community and social capital and producing art".[10] The temporary use of moveable architecture does not only challenge the dominant culture, but also brings a new layer of culture as a result of the exchange of arts and knowledge. New research on the use of moveable

[10] Bishop and Williams, *The Temporary City*: 121-23.

architecture as a practical tool to explore the way in which different cultures combine together in urban life could be proposed, and a further project could investigate the unique image by which moveable architecture – the portable and demountable architecture type – and digital tools contribute to new perspectives on cities and cultures. The assumption is that project owners and clients could use movable architecture to transmit cultures and ideas, and share beliefs which addresses the issue of substantial policy relevance in areas such as cultural exchange and diplomacy, multiculturalism and migration. The aim would be to contribute to communication and engagement with the built environment, by enriching people's understanding of different cultures by creating a moveable architecture database, and providing data for multicultural cities through documentaries, design competitions and films made accessible through collaboration across universities. The research in this area can be concluded by academic researchers, policy makers or organisations, who are interested in urban studies and are willing to promote cultural communication between regions and nations.

Direction 4 – The Economic Power of Ephemeral Architecture

Ephemeral architecture has true potential to promote both tangible and intangible economic opportunities. For example, the Shanghai World Expo 2010 brought significant benefits to Liverpool, UK for various reasons.[11] According to Mike Taylor and Jonathan Caswell, during the event, a value of £2.6 million was achieved and awareness of the Liverpool brand was also raised through social media. The wider benefits included offering platforms for educational communication and international business trading.[12]

Another example is the annual Harbin International Ice and Snow Sculpture Festival that has been held since 1963. Donna Larsen reported that the 2013 annual winter carnival site was 600,000m^2 in total and drew more than 13 million visitors.[13] According to research by architect and urban planner Peter Calthorpe, the festival brings in 14 million tourists, nearly twice the population of London, and an estimated $1.4 billion of economic benefit to the city every year.[14] The Ice and Snow

[11] Mike Taylor and Jonathan Caswell, "Liverpool at Shanghai: The Expo Experience," *Local Economy* 26, no. 5 (2011): 7.
[12] Liverpool was the only UK city except London to have a dedicated Pavilion during the event.
[13] BBC, "China Ice Festival's Giant Crystal Palace," (2013).
[14] Peter Calthorpe, "Introducing the Most Dynamic Cities of 2025," *Foreign Policy* 2012, 67.

Sculpture Festival receives great attention from the worldwide public because of the temporary existence and unique qualities of the structures. The temporality encourages visitors who do not want to miss each year's new designs, and this demonstrates true potential of demountable buildings to be advertised as proudly a limited "window of opportunity".

FIGURE 5. 5. Harbin Ice and Snow Festival 2013[15]

Apart from making commercial profits, the economic power of ephemeral architecture can also be seen from its support for environmental organisations and charities. For example, the Glastonbury Festival – the world's longest running festival, beginning in 1970 – has the capacity to host 180,000 people in tents within a few weeks. The structures onsite also include other mobile structures, such as portable cabins and scaffolding structures.[16] Kronenburg states that a feature of the event is its adherence to green credentials and its commitment to donating a large part of its profits to worthy causes, with Greenpeace, Oxfam and WaterAid its current major beneficiaries.[17]

This rests upon the assumption that ephemeral architecture, especially large-scale projects, have strong capacity to bring economic benefits because it promotes attractive and unusual architectural forms, produces much less construction waste, convenience for open-air events and encourages multidisciplinary collaborations in the industry. It also unfolds a hidden layer of a city which helps it to form temporarily and impacts greatly on social activities.

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[15] Sharon Kwok, "Harbin Ice and Snow Festival 2013," (2013).
[16] Kronenburg, *Live Architecture : Venues, Stages and Arenas for Popular Music*: 191.
[17] Ibid.

A project could be proposed to investigate the unique images created by ephemeral architecture, using the Harbin International Ice and Snow Sculpture Festivals as a case study, with film-making as the main research methodology, to examine the process of the Festival, including preparation, construction, events and dismantling. The production of a documentary film of a "temporary city" created by ice and snow would reveal the facts of how ephemeral architecture can be a powerful tool for pushing forward sustainable economic development.

Summary

The Evaluation Conceptual Model – FFTA (function-finance-timescale-aesthetics) – is currently the only existing comprehensive method that is dedicated to evaluating the functional performance of demountable buildings. The model is based upon a comprehensive range of literature and carefully selected case studies, which were framed as an "explore-proposition-test" research approach. The model was tested on live projects and this thesis demonstrates that it is practical and adaptable for wider disciplines, including exploring new architectural design methods, identifying cultural changes in urban studies, and increasing the economic benefits for different sectors, such as local city councils and small enterprises.

Although limited in some aspects, including the need to further explore the usability of this model to develop a more sophisticated evaluation tool, the research results have established a valuable foundation for future investigations, which benefits academia, architecture and design practice.

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APPENDICES

APPENDIX A

Green & Away Tents Conference Interview Records

Background
Green & Away is a charity and educational organisation providing outdoor conferences, exhibitions, workshops and other environmental events during summer each year. It is a small company in size and relies on volunteers and internships. It aims to establish environmental conference centres with the object of raising awareness in all aspects of sustainable development, including resource and energy use, waste, ecology, health, technology, agriculture, philosophy and psychology.

Website: http://www.greenandaway.org/; **Email:** info@greenandaway.org
Tel: 08704601198
Address: Helen Cranston, Green & Away, PO Box 40, Malvern, WR14 1YS England

Interview Purpose
The purpose of this interview was trying to get involved with G & A summer events, and therefore collecting data from their projects to help with the Ph.D. case studies.

Interviewer
Junjie Xi
Ph.D. Candidate
School of Architecture
University of Liverpool
Email: j2009@liverpool.ac.uk

Interviewee
Peter Lang
Chair of the Trustees for Green & Away
Email: peterlang@talktalk.net
Tel: (0044)02088092391

Time & Date
9:30am, 10 April 2010

Duration
One hour

Location
UKSIF (UK Sustainable Investment & Finance Association), London, UK.

Questions
— *Where did you buy your equipment and tools?*
— Most of our electronic equipment and hand tools are second hand or made from recyclable materials. We bought the majority of them from second-hand markets. We also get our materials from donations because we are a charity organisation.

— *What challenges you the most as the organisers?*
— I would say what challenges me the most is dealing with the people. It is not the equipment or setting up tents or yurts for conferences and accommodation. Sometimes we have to face unexpected situations. For example, last year a girl who

was volunteering with us suddenly decided it wasn't what she expected after a few days and just left. We always need to deal with people's different attitudes and actions to make sure our conferences run well and everybody is happy.

— How many people will you have coming around during the conference time?
— We will have about 200 people on the site at most, and we need to build 50 tents or yurts for that. This year we will hold six events from the beginning of July 'til the beginning of August. We will have our interns arrive on 17 June, then our volunteers will arrive a week after. They will stay with us until 12 August, a week after we finish all the events. We work very hard at the beginning to set up everything and make sure all our equipment runs well. Sometimes we even need to carry on working in the rain because we must have things ready before the people who will attend the conferences arrive. We won't be able to do this without the support from our interns and volunteers. We don't mind a few volunteers leaving for a couple of days for their own thing as long as it's not for too long. Last year, a student joined us 10 days after we started; unfortunately, it didn't work out very well. We need all interns to be there on the first day because we will give a very detailed speech to introduce our objectives and each person's role.

— Could you talk more about the composting toilets and the showers?
— We have 4 composting toilets and 4 hot showers. Some people may find the composting toilet is a challenge at first, but it is actually very sustainable. After we leave, the solid and liquid waste will get dried by the wind and go into the fields. Most people find the outdoor showers are beautiful; you can see the sky and clouds above your head, fresh air as well. Normally, there won't be a queue waiting for toilets or showers, because the people who go to conferences and the people who work on the sites use them at different times.

— What else do you have for accommodation apart from tents and yurts?
— We also use marquees, domes and caravans. Volunteers and interns usually bring their own tents or sleeping bags. If they don't have them, we can offer them some cheaper tents.

Comments

Strengths

1. G&A is not only about "green"; it is also about "away". They remove everything after they finish and leave a clean and green space again. It is a great form of communicating with people and the natural environment.
2. The outdoor conferences and workshops are very different from indoor ones, such as those at a hotel or a university. People get to know each other on a personal level. Most of the people enjoy it very much, especially in summer time. They can also bring their children to experience a productive day out.

Limitations

1. G&A has a limited group of people to work on the sites.
2. G&A needs to respond to the risks of outdoor conferences, such as weather, safety, waterproofing and dealing with emergencies.

Further Activity

It was agreed between Junjie and G&A that Junjie could get involved as a co-volunteer, staying for 2 weeks to do research such as getting to know more about the building structures and the process of setting up the conference village. The timing is likely to be before the end of June 2010.

Green & Away Tents Conference Questionnaire

- This Questionnaire is for Junjie Xi's Ph.D. research in the evaluation of portable architecture **ONLY**.
- Please tick the box in front of your answer. e.g. ☑ Male
- Please feel free to leave comments anywhere on this paper if you wish.

Contact:
Junjie Xi
School of Architecture
The University of Liverpool
Liverpool
U.K.
L69 7ZN
E-mail: j2009@liverpool.co.uk

Are you
☐ Male ☐ Female?

What is your age group?
☐ Under 18 ☐ 18-25 ☐ 25-30 ☐ 30-40 ☐ 40-55 ☐ 55 or older

Are you
☐ Green & Away Organisers ☐ Volunteers ☐Internships
☐ Conference/Workshop attendees ☐ I am here with family/friends
☐ Others________?

How did you travel to here?
☐ By train ☐ By coach ☐ By car ☐ By bicycle ☐ Others_______

How long will you stay?
☐ A few days ☐ A week ☐ Two weeks ☐ Three weeks
☐ Four weeks ☐ I stay for all the events

Are you staying in a
☐ Tent ☐ Caravan ☐ Dome ☐ Shipping container
☐ Others____?

Is this your first time at a tents conference/workshop?
☐ Yes ☐ No, this is my _____time at a tents conference/workshop.

Have you been to any other similar events?
☐ Yes, I have been to____
____
☐ No

Tell me how much are you enjoying here by ticking to the face that best shows how you feel.

☐ ☺ ☐ 😐 ☐ ☹

Which kind of conference/workshop would you prefer?
☐ Conference/workshop in tents
☐ Conference/workshop in universities or hotels

◻ I do not mind.

Would you like to come back again?
☐ Definitely yes ◻ Probably yes ◻ Probably no
☐ Definitely no ◻ Uncertain

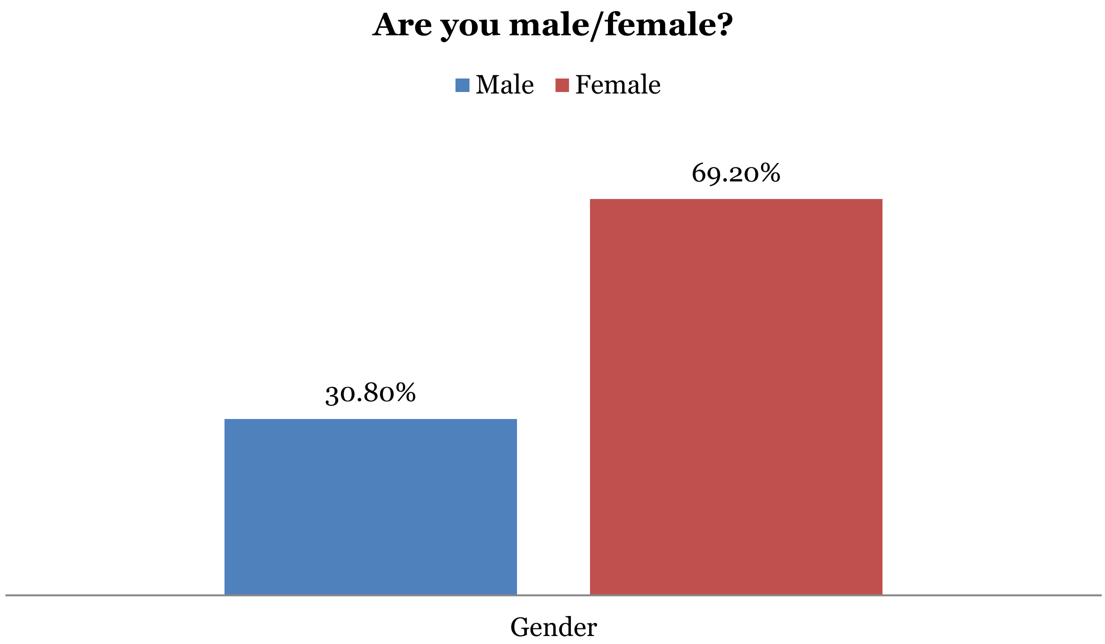
What activity has challenged you the most so far?

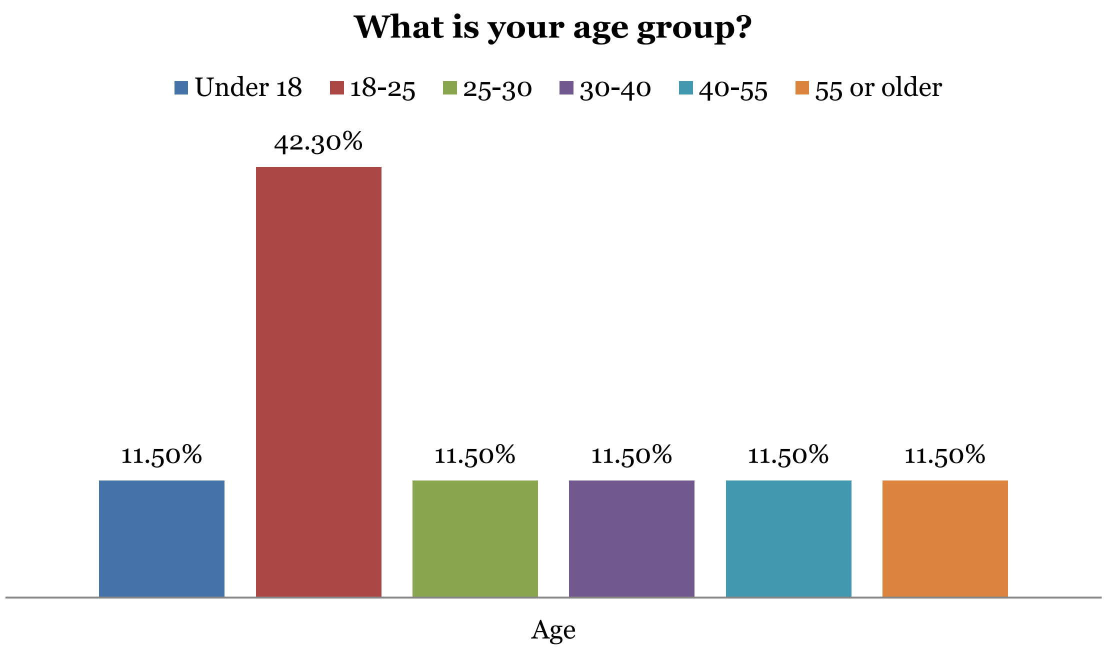
What has been your favourite activity so far?

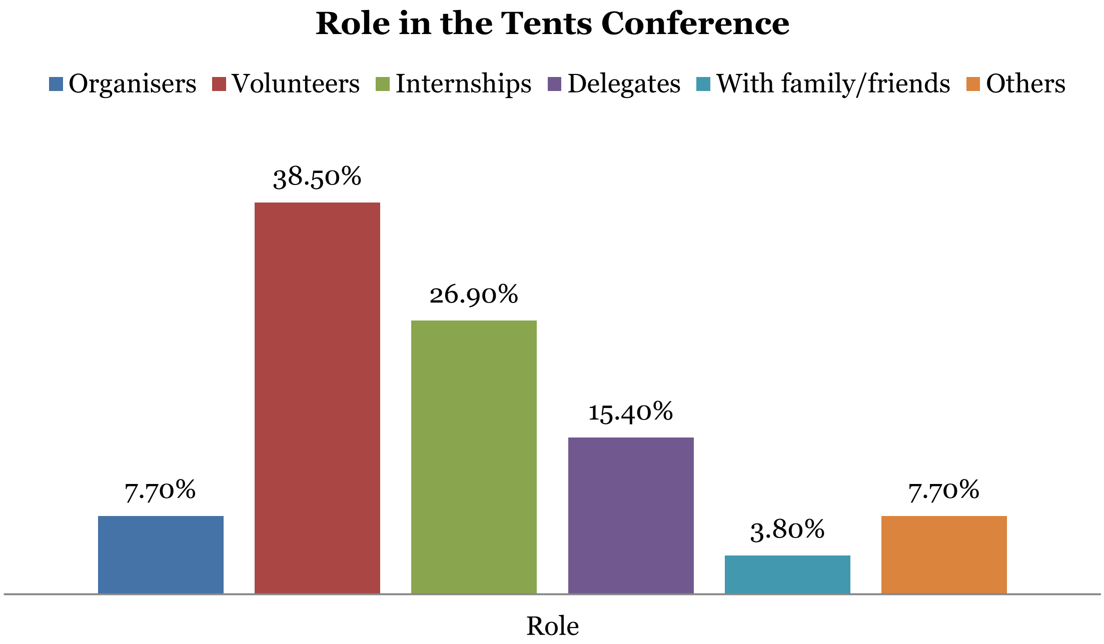
Do you have any other requirements?

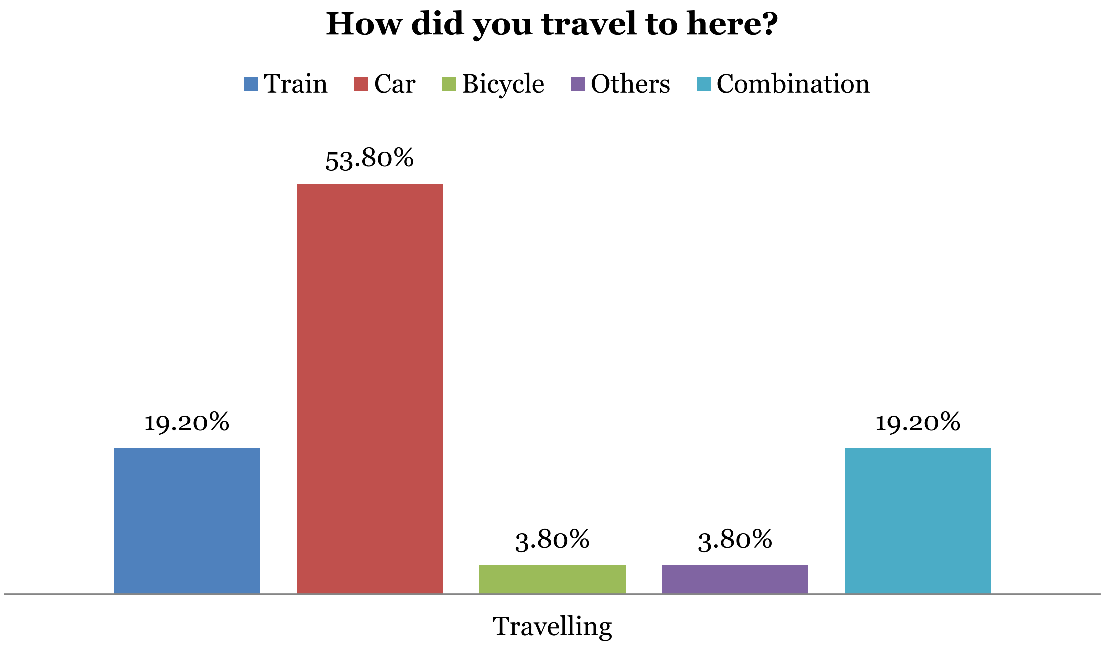
Comments

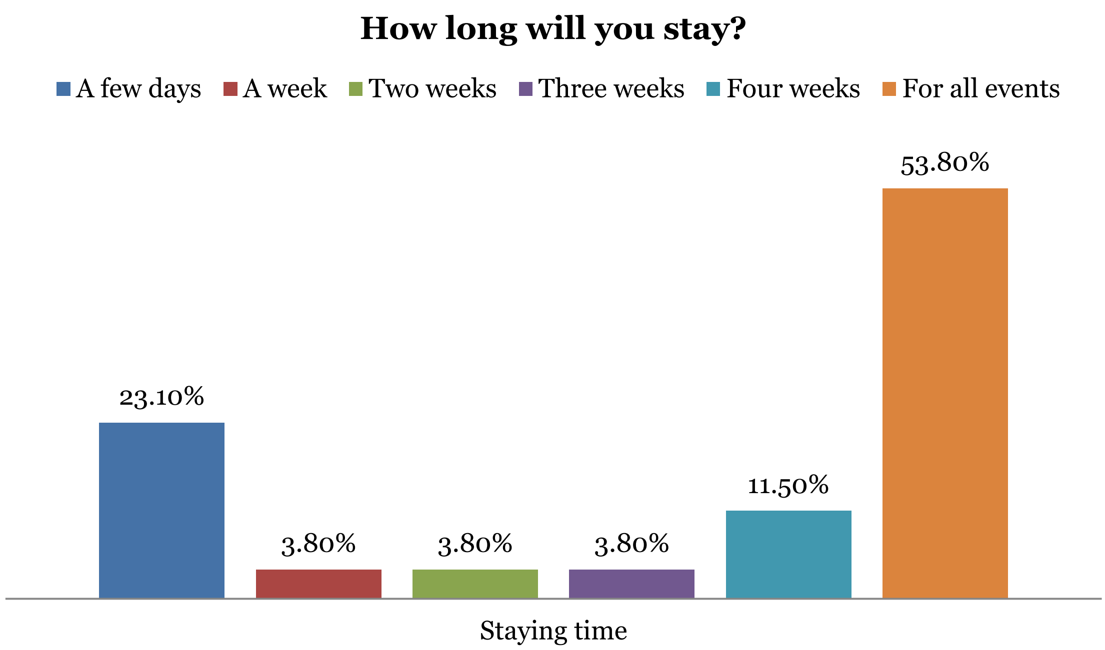
Green & Away Tents Conference Questionnaire Results

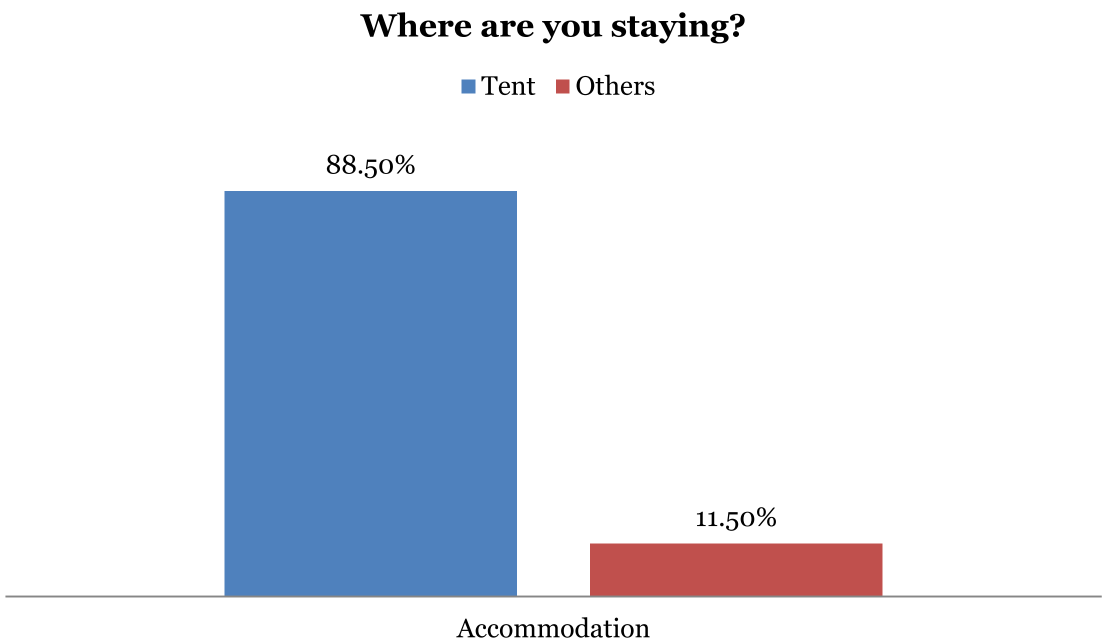


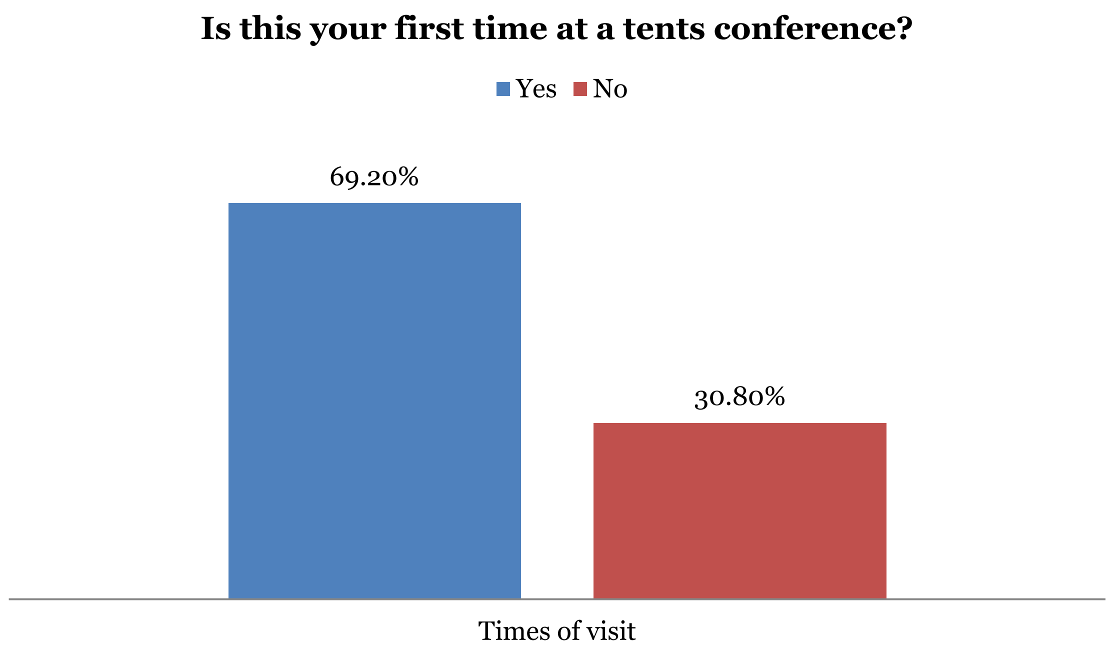


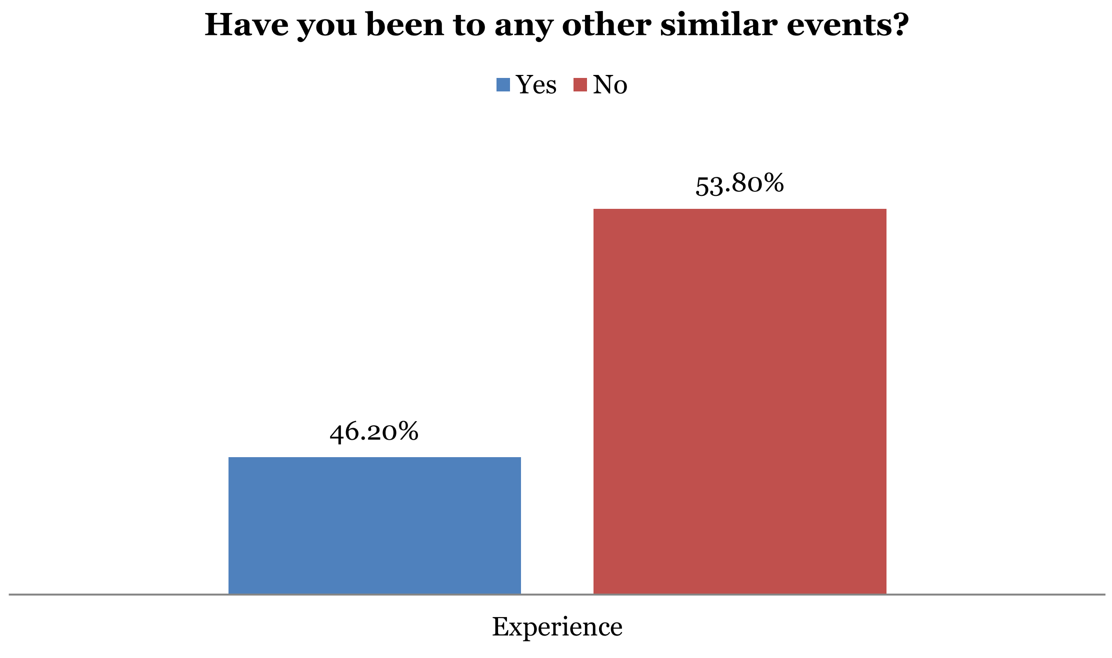

Role in the Tents Conference
Organisers
Volunteers
Internships
Delegates
With family/friends
Others
38.50%
26.90%
15.40%
7.70%
3.80%
7.70%
Role

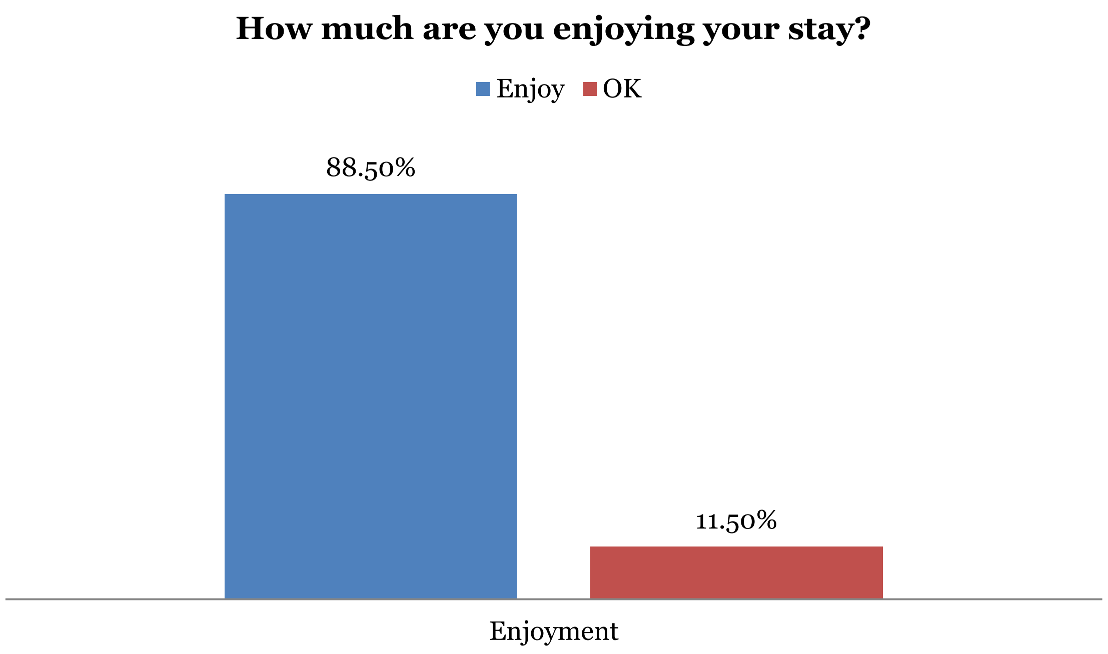

How did you travel to here?
Train
Car
Bicycle
Others
Combination
53.80%
19.20%
3.80%
3.80%
19.20%
Travelling

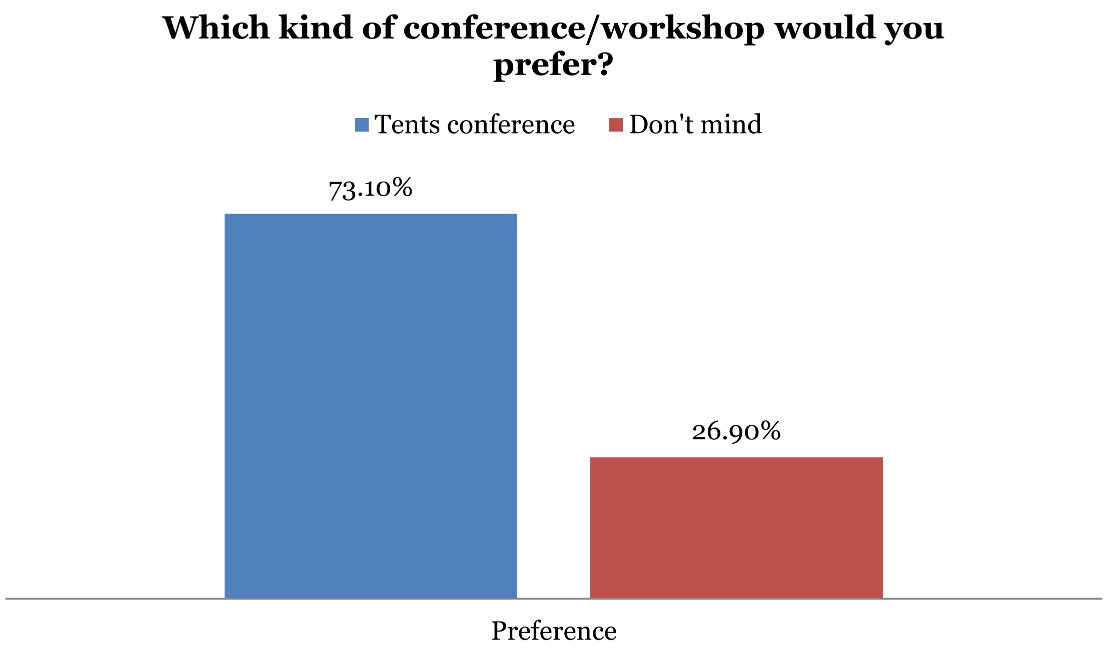

How long will you stay?
A few days
A week
Two weeks
Three weeks
Four weeks
For all events
53.80%
23.10%
11.50%
3.80%
3.80%
3.80%
Staying time

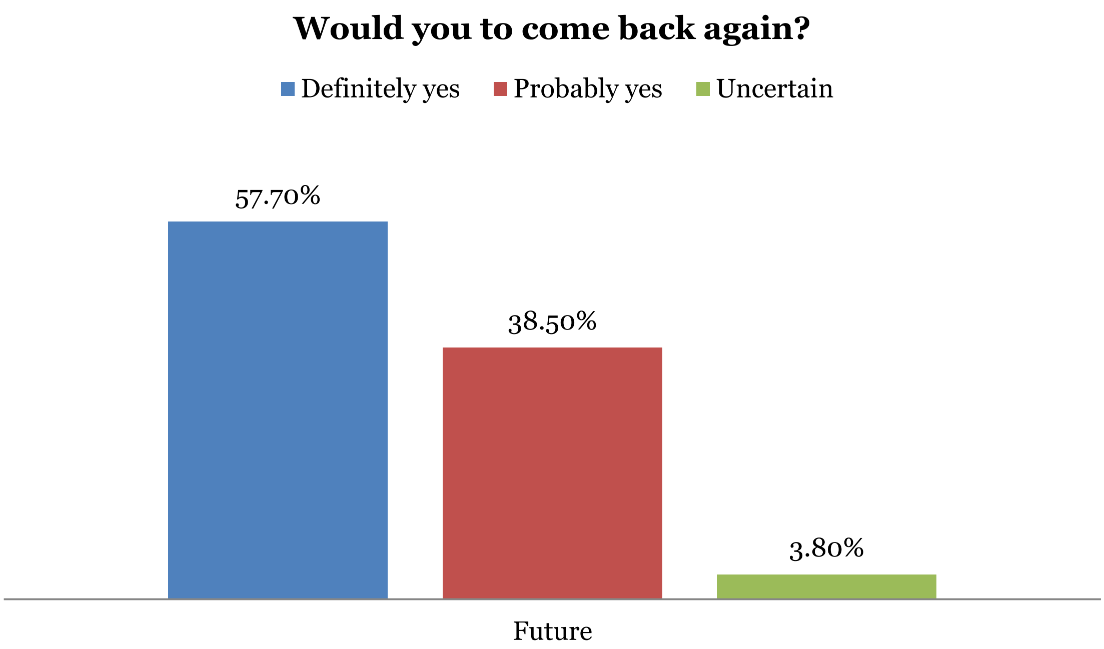

Where are you staying?
Tent
Others
88.50%
11.50%
Accommodation


Is this your first time at a tents conference?
Yes
No
69.20%
30.80%
Times of visit


Have you been to any other similar events?
Yes
No
53.80%
46.20%
Experience


How much are you enjoying your stay?
Enjoy
OK
88.50%
11.50%
Enjoyment


Which kind of conference/workshop would you prefer?
Tents conference
Don't mind
73.10%
26.90%
Preference


Would you to come back again?
Definitely yes
Probably yes
Uncertain
57.70%
38.50%
3.80%
Future

Green & Away Tents Conference Report

Green & Away was established in 1998, and is a charity and educational organisation that provides outdoor conferences, exhibitions and workshops during summer and sometimes in winter every year. In order to obtain a comprehensive understanding of the construction process of demountable buildings, the author visited the site in July 2010 to observe the site, and participated in constructing tents to be used as toilets (including one for disabled users) for the events. The main strategy was to work as a volunteer and get involved with the project coordinators and other volunteers, which enabled the author to gain first-hand experience of the project.

The 2010 summer events were located in Bransford, Worcestershire. The land was rented for a small amount of money from a local farmer, Will Tooby, who also owns The Fold Eco Café and some farms in the nearby area. It was the third year that G&A was holding events on this site, and they decided to use this land as their permanent site. In 2007, G&A was sited at another location in Worcester, near to Bransford, but the whole tent village was nearly flooded due to heavy rain. Luckily, nothing was damaged, and the workshops carried on in the deep mud. The new site was surrounded by a variety of trees, such as apple and cherry. There were also mulberry and cornfields in abundance in the surrounding area. Kevin Cranston, the consultant for the structures, believes that their summer activities do not affect the local natural environment because there are farmers working on the fields throughout the year, so the summer event does not bring any noticeable differences.

The events in 2010 were scheduled from 4 July until 1 August, including six different conferences and workshops: 4–10 July 2010 – The Art of Mentoring; 13–15 July – National Trust Engagement Uncovered; 16–18 July – Humanistic Psychology Earth Festival; 20 July –Green & Away Private View; 23–25 July – Herb Fest 2010: The Association of Master Herbalists Annual Conference; and 29 July–1 August – The Resurgence Readers Weekend & Camp.

The construction and organisation team included seven interns (two of whom were artists in residence) and 25 volunteers. Some of them joined the team at the beginning during the preparation time and some joined during the dismantling time. The interns were required to stay for the whole event, while volunteers had a much more flexible timetable, although most of them stayed for at least three weeks. The team started to prepare the site from 19 June to 3 July, and dismantled the structures for restoration from 3 to 11 August. They had meetings every day at 9am to arrange the daily tasks for each intern and volunteer.

On the first day the site opened, 140 delegates arrived with 25 children, 32 of whom arrived in the morning. The majority of the delegates were attending the tents conference out of choice, while a small number were required by their employers to attend for training purposes, such as the delegates from the National Trust.

FIGURE 1. Green & Away site

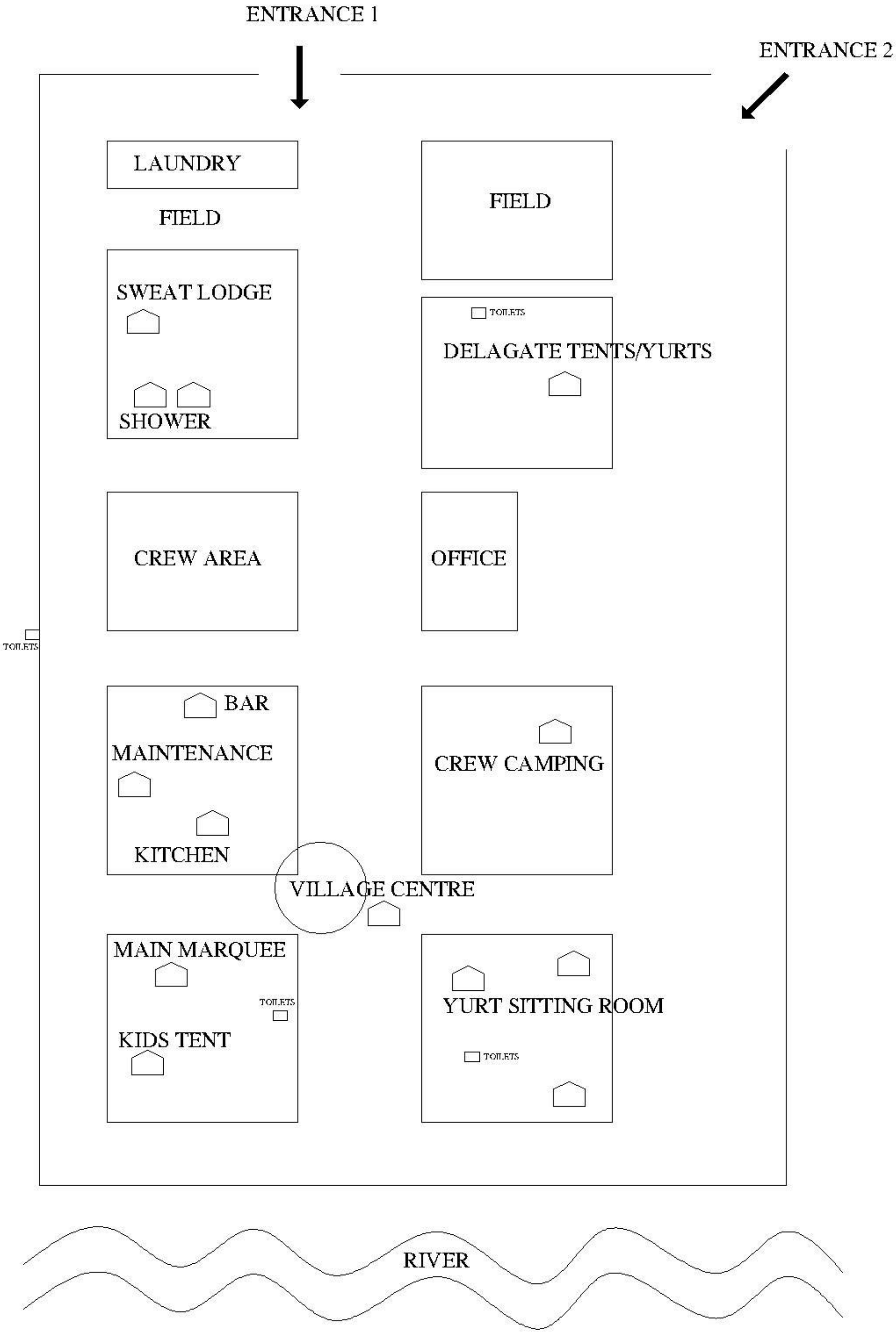


FIGURE 2. The map of the Green & Away site

Types of Structures

The onsite structures included tents, domes, yurts and a few special structures, such as *Peter Pod*. Amongst other materials, the structures were constructed from wood (hazel and willow), string, nylon string, rope, straw, canvas, steel and other small resources.

Dome


FIGURE 3. – FIGURE 4. The geodesic dome; A detailed view of the structure

The material for constructing domes was hazel tree branches, which were freshly cut from the woods nearby. The engineer, Justin Moran, explained that hazel was the best material that they found to build up domes and yurts because it grows quickly and there are a large number of hazels trees near the camping site. This type of construction can last for three to five years if treated well, but normally they will become fragile after winter weather.

Four domes were constructed. One of them had no cover and offered an open space for coffee breaks, art exhibitions and other activities. The three other domes were covered with canvas and were constructed to provide interior events. Green & Away describes the benefits of using domes:

> A geodesic dome is also a really useful structure because it can be packed away into a very small space – all you need are the poles and the connectors. The other advantage to this is that if one of your edges gets lost/broken/disintegrated, you can easily replace it with a new one. [1]

However, because the geodesic dome structure is light in weight, they can begin to float if the air inside gets considerably warmer than the outside. However, this safety

[1] Green & Away, "Green & Away 2010.".

caution is only for the domes covered with canvas. An open-sided dome can have alternative choices for use, such as the art exhibition that was named "The Story Trail". Many colourful umbrellas were hung from the dome, and small notebooks were attached with stories inside written by volunteer Andy.

FIGURE 5. – FIGURE 6. The Story Trail art exhibition; Umbrellas hung from the dome

Tent

The tents that were used included the main marquee, cotton/canvas tents and nylon tents. The main marquee was the centre of all the conferences and workshops, and it had the capacity to accommodate around 40 delegates at the same time. The structure was built directly on the grass and supported by two 3-metre-tall wooden columns. The main advantage of using this marquee was that it was installed open-sided to allow easy access for people and ventilation.

FIGURE 7. – FIGURE 9. The main marquee; A canvas tent; A group of nylon tents

Cotton and canvas tents were used as luxury accommodation, a temporary bar (bell tent) and one disabled toilet. The construction required at least two people to work together, and the steps were:

- Unpack the tent.
- Lay out the ground sheet as flat as possible and pin it down with the small pegs to stop it blowing away. The longer side is where the door is.

- Lift tent onto the ground sheet with the entrance facing the desired direction and make sure the door is fully zipped up.
- Peg the two rubber loops either side of the door together right next to one of closest peg in the ground sheet. Repeat this all the way round the tent.
- Get the poles out and extend them.
- Stand next to the pole and adjust the bottom to make it as upright as possible.
- Get the A-frame and enter the tent.
- Leave the tent and using the large pegs.
- Go inside the tent and tuck the walls under the ground sheet.[2]

Nylon tents were the simplest and lightest tents on site, although they were not strong enough for adverse weather conditions. They were set up on the site for the volunteers to camp in during construction and dismantling time. Most of the volunteers brought their own nylon tents, although free tents were available to use and supplied by G&A. Through experience, the author discovered that the temperature inside tents rises to extremely high during the daytime and goes down in the night. Because all the tents were set up directly on the grass, the interior became cold and wet during the night. A critical problem was during rainy days, when the soil became sodden; the pegs often started shifting in the ground. The only solution was to check all the pegs regularly to prevent the tents collapsing.

Yurt

FIGURE 10. – FIGURE 12. The small yurts; The main yurt; The roof of the yurt

The small yurts (Figure 10.) for accommodation use were purchased from Woodland Yurts – a family company from Clevedon, North Somerset, UK that hand-crafts yurts for sale. The main benefit of using yurts for conference delegates was that they were stronger than tents or domes. The drawback was that they were more expensive to buy, and it takes a longer time to recuperate the costs. All the decorations in the yurts were purchased from IKEA, and each yurt was rented for £27 per person per night.

[2] ———, "Green & Away Instructions for Erecting Tent.".

The main yurt (Figure 11.) offered a large sitting room for events participators. The structure was constructed from 72 hazel rods, willow, bamboo, 40 metres of 3–4mm nylon woven string and 7 metres of rope. The most challenging process was stringing up the structures, because this process requires heating the end of the string over a lighter flame to soften it. If not careful, the string could easily be melted and thus not used for construction. Constructing the roof wheel (Figure 12.), also called *the crown*, was a difficult task as well. It provided the major lighting inside the yurt, and could be arranged in patterns. Another function of the roof wheel was that it provided the ventilation access for the chimney in the centre of the yurt. During the daytime, the temperature inside all yurts rose quickly because the structure was covered with heavy waterproof canvas and the front door was the only access. Once the front door was zipped up or covered with canvas, there was no ventilation, which was a negative aspect of using yurts during summer.

Peter Pod

FIGURE 13. Peter Pod

Peter Pod was designed by Dina Jung – a design and technology teacher based in London. The structure was designed especially for elderly people or people with disabilities. Jung's idea for Peter Pod was inspired by the gypsy caravans, which are light in weight and can be easily transported. The disadvantage was that it had a small door and only one window on one side, which was the only interior lighting available. Although in theory Peter Pod was designed for the elderly or disabled, it had extremely limited space inside, which meant that it was not suitable for wheelchair users or people with mobility difficulties.

Strengths

FIGURE 14. – FIGURE 16. Solar power panel; Wind power;[3] Wood power

- Successful in raising the awareness of protecting the natural environment. Electricity was only used for charging laptops, mobile phones and supplying one washing machine. Solar and wind power were used for supplying warm water for the kitchen and showers.

- G&A provided a different way of experiencing conferences and workshops. Upon gathering questionnaire information, it showed that the participators felt more connected during camping in comparison to attending conferences or workshops in an urban environment.

- Most of the construction tools were purchased from second-hand charity shops, thus reducing costs even further. All of the wood and timber used in construction was felled or gathered from the surrounding areas after the landowner granted permission.

- There was no involvement of wages for the construction workers, because they were all volunteers. Their food was provided by G&A from the income obtained from the conference delegates' fees and charges. This income was also used for purchasing new facilities, such as ovens and construction tools.

- The last event finished on 1 August, and all the tents, yurts, domes and composting toilets were dismantled quickly within ten days. All the structures, components and other facilities were transported away from the land and stored in four shipping containers for next year. The land was returned to being clean and quiet, without any damage after two months of intense activity.

[3] A strong timber was erected and connected to the wind turbine. By pulling the timber down, the wind turbine could be lifted up at the same time.

Weaknesses

- The first weakness was that the tents conference could not cope well with heavy rain, as rain water could easily cause the structures to be unstable and make it impossible for outdoor activities to continue.

- No lighting was available, apart from two lights in the bar and one light in the kitchen, which were supported by solar power during the night. Those lights, however, were switched off at 10pm, and the delegates could only rely on torches at night-time. This was not convenient for visitors with disabilities.

- There was a clear lack of creativity in construction and the development of more sophisticated designs. Many construction plans have been in use for over ten years, and there were no new designs evolving.

- The co-ordinators believed that every visitor who came to G&A should enjoy their time. If they did not, the reason was seen to be because of their lack of preparation in terms of camping equipment or clothing. Little consideration was given towards improving the comfort of the provided structures.

- Although G&A has developed from a small group of people who were interested in working more efficiently to reduce people's environmental impact into a well-organised charity, there is a lack of professional training given to the construction volunteers, and most of the construction and technicians' tools were a decade old; thus, they had little ability to improve the quality of the structures.

APPENDIX B

The Mina Improved Tent Project Questionnaire[4]

Moshabab Aljarman: I was a supervisor engineer at the same site but in buildings belonging to the project. Please note that the following answers were answered from the memory of the participant without going back to references, so you may need to contact the Ministry of Municipal and Rural Affairs for specific or further information.

General Questions

- How did this commission occur (date, client)?
  - 1996, the client was the Saudi Ministry of Public Works and Housing.
- Who is the designer of this project?
  - The ministry experts at the Ministry of Municipalities and Rural Affairs with the German company.
- How was the designer company selected?
  - There was no competition advertised, but it was a direct contract with a German Company (SL - Rasch).
- Were there any specialist consultants involved in the design briefing?
  - Yes, there were a number of specialists and experts from the ministry and outside.
- What were the most important design criteria requested by the client?
  - To be fire-resistant and bear high temperatures exceeding 70 ^{o}C.
- Did the client or the design team prepare most of the design brief?
  - Yes, and they proposed different designs. The final design was selected based on the criteria of materials.

Design

- How many types of design (tents) are there?
  - 8×8 m, 8×6m and 8×12m. Currently there is one design on the site, but it is flexible enough as a unit (or module) to fit different sizes and sites.
- How much was the design service?
  - Four billion Saudi riyal for all design, supply, installation and implementation.
- How long was the design process in total?
  - Around 2 years, and I remember the last stage was 2001.
- According to the design brief, how long are the tents expected to be used? (durability of the tents)
  - 50 years
- Is there a map available indicating the location of each tent/camp?
  - Yes

Construction and Transportation

- Where were the tents manufactured?
  - In Saudi Arabia
- Was it difficult to find suitable manufacturers/contractors?
  - Yes, because the materials were not sufficiently available to the huge number required.
- How were the tents transported to Mina?

[4] The questionnaire was sent to Moshabab Aljarman on the 5th December 2012. Aljarman is an engineer at Ministry of Municipal & Rural Affairs in Saudi Arabia.

- There were some factories that were temporarily built for this purpose closest to the locations, then transported to the sites via big trucks.

- Were all the tents transported to the construction site at the same time or at separate times?
  - At the same time and after finishing the stage of the construction of the tents in the factory, because the time was critical.
- How long was the construction process in total?
  - I think there were three phases but I am not sure. You can refer to the Ministry in this regard. There is an article in the newspaper to prove it.
- How much was the construction cost (machinery, material, workers)?
  - You can refer to the Ministry in this regard.
- In which year was the project completed?
  - 1996–1997 , 2001

Operation

- Do pilgrims prefer to stay in the tents or permanent houses/flats during Hajj? Why?
  - They prefer to stay in the tents because of the Islamic policies and regulations for this event.
- Are all the tents left empty after Hajj?
  - That's right, and closed.
- How are the tents being maintained?
  - They have been built to a very high quality to cope with extreme and harsh weather. The Ministry of Hajj is responsible for maintenance and operation.
- How often are the tents checked for safety issues?
  - Every year before the event of Hajj starts.
- How many tents have been replaced since the project was completed?
  - So many, because the holy places are now undergoing stages of large development projects, and therefore witnessing the implementation of large projects that require tents to be unpacked and modified from one period to another as needed.

Future

- What do you think are the advantages and disadvantages (if applicable) of the design of the improved tents?
  - Flexibility, durability, and fire-resistance.
- Did the authority examine/evaluate the Tent Project? If yes, how?
  - Yes, the Ministry has big laboratories to examine the concrete and all the building materials including tents.
- If any tent needs to be replaced, is it the same manufacturer that fabricates the new tent?
  - Yes, because the companies that made the tents are local Saudi companies – for example, Al-Obaikan Company. From time to time the Ministry requests some tents from these companies as needed to the same quality and specifications.
- How long will these tents remain in use? (As long as possible or there is a plan to replace them at some time in the future?)
  - I think the tents have been constructed and made to be long-lasting for at least 50 years; however you can refer to the Ministry in this regard.

APPENDIX C

Questionnaire to the Chengdu Hualin Elementary School Pupils[5]

- This Questionnaire is for Junjie Xi's Ph.D. research in the evaluation of demountable building **ONLY**.
- Please feel free to leave comments anywhere on this document.

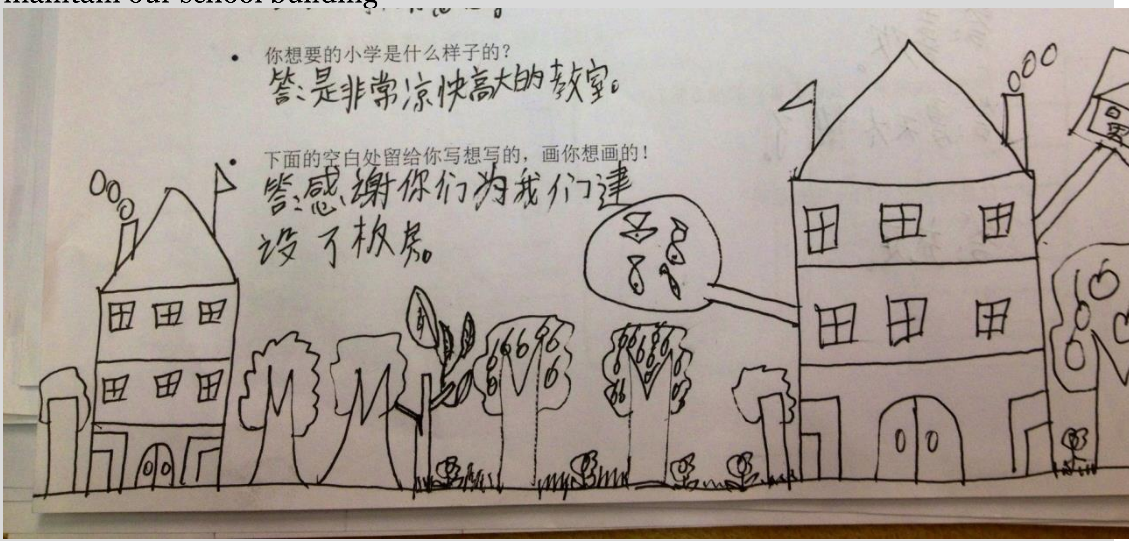
Contact:
Junjie Xi
School of Architecture, University of Liverpool
Liverpool, U.K.
L69 7ZN
E-mail: j2009@liverpool.co.uk

- Which grade are you in this year?
- What is your memory of the old school building before it was damaged?
- In which row do you sit inside the classroom (left, right or in the middle)?
- Does it feel extremely hot to study in the classrooms in summer?
- Does it feel extremely cold to study in the classrooms in winter?
- Do you think the current building that you are studying in looks pretty?
- Do you enjoy studying in the current classroom?
- Is there anything that you dislike about the current classroom?
- Is there adequate light for you inside the classroom?
- During class time, can you hear the noise from the road? If yes, does this affect your study?
- During class time, can you hear the noise from other classrooms? If yes, does this affect your study?
- During class time, can you hear the noise from the playground? If yes, does this affect your study?
- Is there enough space for you to study inside the classroom?
- What does it feel like to study inside the classroom during rainy days? Have there been any problems with leaking?
- How and where do you spend your class break-time?
- In your opinion, what are the differences between the paper school and the old school building?
- Are you looking forward to moving into the new campus?
- What are your parents' opinions on the paper school?
- Do you remember the volunteers who constructed the paper school in 2008? Did you find their work interesting?
- Please describe your ideal school.

[5] The original questionnaire was written in Mandarin and it has been translated into English to be included in this thesis. The pupils who participated in this questionnaire were aged from eight to ten. The author used the most basic words and tune of language for the pupils to understand.

Selected Comments from the Pupils at Chengdu Hualin Elementary School

Positive	Negative
"thank the volunteers who built this paper school for us"	"it feels too hot in summer"
"thank the volunteers who constructed this paper in 2008 and provided us a good study environment"	"the school now is too hot, the old school was too cold"
"I hope the paper school will be there forever for us to remember the volunteers"	"I can hear the noise from the rain drops hitting on the roof during rainy days"
"the paper school is very pretty"	"the classrooms are very low in height"
"I remember the Japanese volunteers, I think their work was very interesting, creative and sustainable"	"the classrooms are very low in height"
	"I hear the noise from other classrooms when they have musical classes and it affects my study"
"I like the school now because I don't need to climb steps"	"the classroom feels very wet during rainy days"
"the paper school is very safe to use for disaster relief"	"I hope there will be more ginkgo trees"
"there was no TV before, now there is TV"	"I don't like the desks"
"the classroom now is not hot"	"very cold in rainy days"
"the classroom is very natural"	"the toilets are too far from the classroom"
"the is plenty of space in the classroom"	"I hope there will be more trees"
"I think there is adequate lighting in the classroom"	"the classroom is smaller than before"
"I enjoy studying in our classroom"	"I don't like the cleaning corner in the classroom"
"it feels magical inside the classroom during rainy days"	"during lunch time, there is too much light inside the classroom and I cannot rest well"
"I feel happy when it rains"	
Comments: "hope the volunteers who helped us can read our comments and maintain our school building"	



Questionnaire to the Volunteer Students

- This Questionnaire is for Junjie Xi's Ph.D. research in the evaluation of portable architecture **ONLY**.
- Please tick the box in front of your answer. e.g. ☑ Male
- Please feel free to leave comments anywhere on this document.
- It is suggested to use English to complete the questionnaire, but please feel free to use your own language if you find it more comfortable.

Contact:
Junjie Xi
School of Architecture, University of Liverpool
Liverpool, U.K.
L69 7ZN
E-mail: j2009@liverpool.co.uk

Are you
☐ Male ☐ Female?

Is your age
☐ Under 18 ☐ 18-25 ☐ 25-30 ☐ 30-40 ☐ 40-55 ☐ 55 or older

How did you hear about volunteering in Chengdu Hualin Elementary project?
☐ Internet ☐ Emails ☐ Telephone ☐ Word of mouth
☐ Others_______

How did you arrive at the construction site?
☐ By plane ☐ By train ☐ By coach ☐ By car ☐ By bicycle ☐ Others_______

How long did you stay?
☐ A few days ☐ A week ☐ Two weeks ☐ Three weeks
☐ Four weeks ☐ I stayed until completing the project.

What is your training/academic background?
☐ Architecture ☐ Engineering ☐ Design ☐ Art
☐ Others_______

Have you received any training courses in building contraction before the voluntary work?
☐ No
☐ Yes,____

Was the design concept difficult for you to understand?
☐ No
☐ Yes,____

Was the construction plan hard for you to follow?
☐ No
☐ Yes,____

Was it the first time you use paper tubing as a building construction material?
☐ Yes
☐ No,____

What team were you in?
☐ Fast stage ▫ Slow stage ▫ Both

Have you been involved in any other similar projects before?
☐ No
☐ Yes, I have been to______________________________________

Are you working on any temporary/portable/mobile building projects?
☐ No
☐ Yes,____

Do you think your construction skills have been developed since your joined the volunteer team? /In what aspects?
☐ No
☐ Yes,____

What was your role in the project?

____

____

What activity had challenged you the most?

____

____

Did any unexpected issues happen during your work? How did you solve them?

____

____

What you could have done differently next time?

____

____

What do you think are the advantages of this design?

____

____

What do you think are the disadvantages of this design?

____

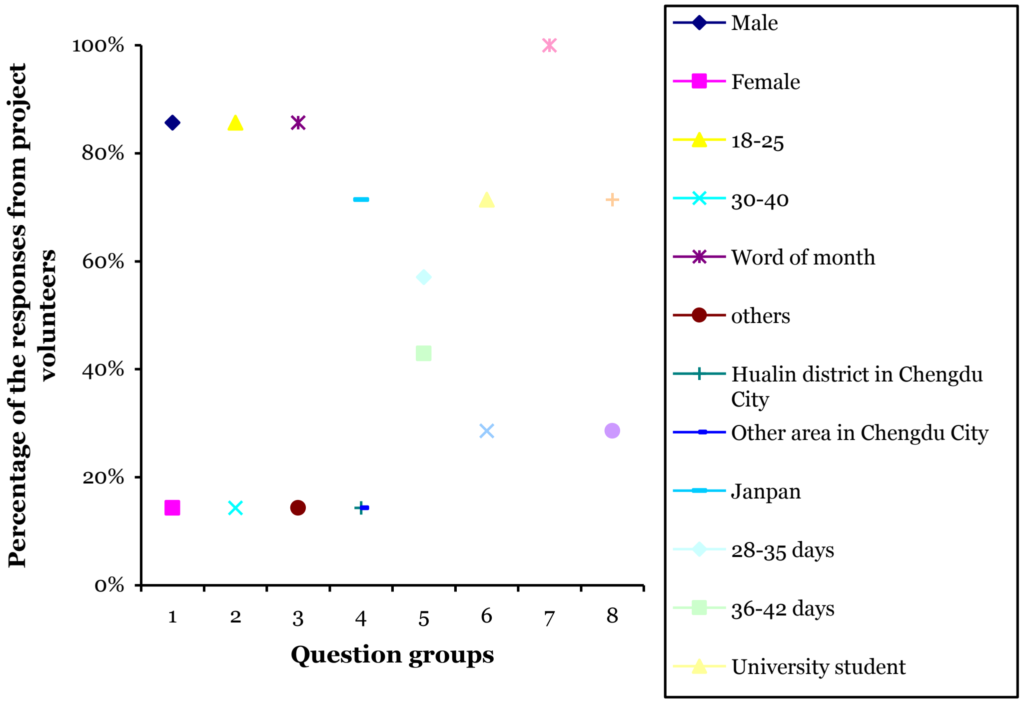
____

Comments

____

____

Synthesised Questionnaire Results to the Volunteer Students



General information (This general information is based on the volunteers who participated the online questionnaire, it does not cover all the volunteers).	• 86% male volunteers, 14% female volunteers • 86% volunteers are aged between 18-25, 14% are between 30-40 • 86% volunteers heard about the volunteering from word of mouth • 57% volunteers stayed on site for 28-35 days, 43% stayed for 36-42 days • 71% volunteers are university students, 29% are graduated • 100% volunteers have architectural training background • 71% volunteers received training courses in building construction before the voluntary work, 29% did not.
Was the design concept difficult for you to understand?	• Its concept is obvious and normal for us who major architecture. Besides every time before we start the work we will have a meeting to show the detail. • slightly developed, compared to other emergency shelters by paper tubes • Size wise and program wise. Although it follows the same concept, simple and understandable. • No. It's quite clear. • It was a big challenge to complete a project in 40days using a paper tube which is not familiar material for most of people. • It didn't seem difficult. Because I was in Ban Lab where Prof. Ban taught us the concept before getting down to it
Was the construction drawing/schedule hard for you to follow?	• No • Maybe just a little. • Constructing a structure that large in one month was a challenge. • It was. When I was in the project, it was my first semester as an architecture student, like who had almost no knowledge about it. To build in practice, not design was reaching to understanding of details of architecture. That's why I felt so. • Yes. We had been behind the schedule because of external elements like weather, delayed supply of construction materials. • There was a deadline to complete because we needed to

	finish the project during the summer vacations of the pupils. So we solved a lot of problems all together.
Was it the first time you use paper tubing as a building construction material?	• It is the first time for me to use this unusual structure • It was not. Before it started, I did that for study in Ban Lab at University. • There were former projects I participated which were designed with paper tubes. • Paper Tube Studio at Keio University Paper Tube Studio as Paris Paper Log House at exhibition
Have you been involved in any other similar projects before?	• It was first time. • Yes, I have been to paper shelter, paper log house, paper partition system and many others including non-paper, non-temporary structures. • projects of Shigeru Ban • Niigata earthquake in 2004 Tsunami rehabilitation in Sri Lanka in 2005
Are you working on any temporary/portable/mobile building projects?	• individually, a shelter to be built in the Himalayas • Shigeru Ban's (projects)
Do you think your construction skills have been developed since you joined the volunteer team?/ In what aspects?	• It is very helpful for me especially in broadening my thought. • Yes. I realized what happens normally on construction is different from designing in studio, which means there were some gaps, warps we had to adapt. In this aspect especially, I learned some ways to do with not only machine also our hands. • skills on tools, knowledge in construction methods and process, • Yes. A lot. • I developed on site communication skills, especially. Also, it helped me broaden my sight of "architectural design". • to work as a team was a big aspect • Not only volunteer team, but also I developed the skill of the construction at the studio of Keio university as using a craft tools or making a drawing as easy to build.
Do you find the voluntary work experience helpful to your further study and career?	• I believe that it open a new start for my interest. • I do. I would like to study what a temporal things bring out in daily life. • Hope so. However it's not the reason why I participated in the project. • it is a big chance to learn many things not taught generally in school • I learned that I can work for the people who need a building to live. Not for the luxury.
Will you join the similar projects again in the future?	• I would like to join. • I hope. • If there is a chance. • I will. • If I have the opportunity.
Did you enjoy working with other volunteers?	• This cooperation leaves a wonderful memory for me. • That was one of most impressed portions. • Always encouraging, especially when international. • Yes, very much. • to communicate with the Chinese people were difficult, but yes • I enjoyed.
What was your role in the project?	• I nearly participate in the whole process, so I have many roles. • One of student participants. • leading other students on constructing, communicating with the manager and master carpenter on construction process • Drawing and Directing Chinese contractor and volunteer workers who didn't know what to do.

	• part of the Shigeru ban team from the university in Japan • Project architects and volunteer leader.
What activity had challenged you the most?	• The section when i work in the roof, I find it is more challengeable than in the ground. • I climbed up on the roof and felt scary a little bit. • Mostly communication. Managing the construction process. • The communication among the Japanese and the Chinese, which is secondary (in my view, dominant) achievement of this project. • to communicate and work as a team with the Chinese students and carpenters • To finish the project such a short time.
Did any unexpected issues happen during your work? How did you solve them?	• Some join points which were produced in the factory are week in the intensity. So we have to justify our method of connection. • Weakness of some of the materials, due to its quality. Solved by compensating, but had to be slightly compromised design wise. • Most of the problems (like budget and schedule) were finally solved by managers (professors). So we could concentrate on building itself. • lack of materials and the pressure of construction schedule, quality of work of Chinese carpenters, and so on • The system of the payment is totally different for me but Chinese team tried to make it more easily.
What you could have done differently next time?	• The proficiency and cooperation. • Setting the materials and structure to be easily adjustable. • Organize small groups mixed both the Japanese and the Chinese. By doing so, people feel unified and become responsible for their job. • research on the area in means such as where to get the right materials could have been done forehand unexpected things always happen and is hard to predict
What do you think are the advantages of this design?	• It is easy to operate for most of volunteer. • It could be built not difficulty by anyone. • Simplicity at most. Easily constructed, also on deconstruction. • Flexibility and easily expanded. • easy-assemble and unique design • it can be built by volunteers • We can find a paper tube factory in most of countries. Usually the price of the building material goes up after the huge quake because the balance of the demand and supply are broken. But paper tube is not a building material. It is industrial product which is not affected by the quake. And there is no carpenter who has a good experience to use a paper tube as building material so we designed it as easy to build by the people who does not has an experience of the construction. The price of the labour will also increase after the quake but if you use a paper tube, we can work with volunteer.
What do you think are the disadvantages of this design?	• It is not so comfortable for the users. • Easiness on combining the elements can lead the structure elements getting out of alignment. • Cost (don't know how much) and flammability. • since the scale of the building becomes big, it becomes harder for non-skilled people to construct • Tube is not easy to build. Rectangle section like a timber is easy to build in most of cases.
Comments	• In a word, though maybe there are some little shortages, the whole process and the result are wonderful.

	• This research reminds me of that amazing experience. I remembered my motivation about design which I had when I started to study this subject. • overall, it was a great experience to take part in this project good luck on your research • Not only the designing, the corporate working with people from different countries makes good affection to the understanding each other. So the process of the construction was more important than the construction in the normal occasion.

Interview Records (via phone)

Background

Mr Deng was the project coordinator for Chengdu Hualin Elementary School. His duties were to organise volunteers and make sure the project finished on time and was of a satisfactory quality.

Interview Purpose

The purpose of this interview was to obtain information that was not available through publications or the Internet, and gain an insight into the project from Deng's experience.

Interviewer

Junjie Xi
Ph.D. Candidate
School of Architecture
University of Liverpool
Email: J.Xi@liverpool.ac.uk

Interviewee

Jing Deng
Associate Professor of Faculty of Architecture Southwest Jiaotong University, China
Email: darej@126.com

Time

2:30pm, 17 June 2010

Duration

Half an hour

Questions

Project Management

— *What has been the most challenging activity for you as the coordinator?*

— Before the Hualin Elementary School project, we didn't have any previous experience of constructing a building from paper tubing. Apart from this, there was some delay; for example, we were not allowed to do extra work during the Beijing 2008 Olympic Games outside the normal working hours, and we also couldn't work when it was raining. But overall, the most essential reason was the lack of experience of using the paper tubing as a construction material.

— *The project budget was 580,000 RMB, but how much were the real costs?*

— I am not 100% sure, but I guess it was around 680,000 RMB. We also needed to provide volunteers with breakfast and temporary accommodation if they came from other cities.

— *Who were the funding bodies?*

— Shigeru Ban Architects and the Chengdu Education Bureau.

Design

— *Are there any similarly designed shelters?*
— No, Hualin Elementary School was the only one.

Procurement

— *Was all the material purchased in Sichuan?*
— We bought the paper from Guangdong (southern China), as they had better techniques in making the paper we required.

— *Where were all the building materials and machinery from?*
— Most of them, such as cutting machines, were borrowed from Southwest Jiaotong University, and other resources, such as nails, were bought from Chengdu.

Construction

— *How many times had Shigeru Ban been on the site?*
— If I remember correctly, it was around 4 or 5 times in total. On his first visit, he came with Beijing Matsubara to propose his idea to the local government officials.

— *Were there any communication difficulties between Chinese volunteers and Japanese volunteers?*
— The project was finished with only minor delays and to an acceptable standard. But because of the culture differences and different training backgrounds, there were some oral arguments between them. For example, some Chinese volunteer students didn't arrive at the site on time, which caused discontent in the Japanese volunteer students. My job was to calm the situation down and continue with working hard.

— *Were there any communication difficulties between the designers and the construction team?*
— Not really. Shigeru Ban came with Beijing Matsubara and the Architects. They have previous working experience of dealing with the construction industry in China, so overall there wasn't any difficulty in communication or in the culture differences.

— *Were there any errors between the design concepts and the construction? Why did they occur?*
— Yes, there were some errors and yet again the major reason was insufficient knowledge and experience of using paper as a construction material. I believe that the errors were overcome by the passion of the volunteers involved, which resulted in just minor delays to the project.

— *How many volunteers joined? Who were they?*
— The total was 127, of whom 94 were Chinese, 25 were Japanese, and 8 were volunteer organisers (including Shigeru Ban and Matsubara Hironori).

— *Did the volunteers carry out the whole project?*
— No, we had professional building workers on the site as well to do the difficult parts of the structures.

Future

— *Is this temporary school going to be taken down?*
— Yes, it will be taken down after the new school is completed. The paper tubes are 100% recyclable. Other materials, such as the PVC windows, can be used

in other buildings.

— *How long has the project been used? Have the pupils and their teachers moved to the new permanent school?*
— It has been used for 2 years now. I am not sure if they have moved yet.

Comments

Useful and interesting information was gathered from Mr Deng, with explanations of how the team overcame the problems that arose. Mr Deng also provided contact information for the team leader of the volunteers (Lin Hou) for further study.

Chengdu Hualin Elementary School Evaluation Questionnaires – Completed by Yasunori Harano and Reiji Watabe on 4 December 2012

Design Quality Indicators of Small-Scale Public Demountable Buildings (Post-Occupancy Evaluation)						
Instructions	The Conceptual Evaluation Model was developed by Junjie Xi as a part of the research results in the evaluation of small-scale public demountable buildings. There are 27 indicators in the model. Please select the checkbox that you feel is most suitable for your design. Please only select one option for each indicator.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
	Performance Indicators	**1**	**2**	**3**	**4**	**5**
Function	1. The thermal comfort quality (temperature and humidity) is appropriate for its use.	☐	☐	☐	☐	☐
	2. The acoustic quality is appropriate for its use.	☐	☐	☐	☐	☐
	3. The spatial comfort quality is appropriate for its use.	☐	☐	☐	☐	☐
	4. The design for disabled users is well planned.	☐	☐	☐	☐	☐
	5. There is circulation space left for the emergency exit.	☐	☐	☐	☐	☐
	6. The furniture can be well arranged inside the building.	☐	☐	☐	☐	☐
	7. It is convenient for the promoters/clients to use the building/structure.	☐	☐	☐	☐	☐
	8. The building/structure will weather well and can be easily maintained.	☐	☐	☐	☐	☐
Finance	9. The final cost of the construction materials, building machinery and tools is appropriate for the budget.	☐	☐	☐	☐	☐
	10. The final cost of the physical plant is appropriate.	☐	☐	☐	☐	☐
	11. The final cost of disposing of waste building/structure materials is appropriate.	☐	☐	☐	☐	☐
	12. The final cost of dismantling is/will be appropriate.	☐	☐	☐	☐	☐
	13. The final cost of transportation after dismantling will be appropriate.	☐	☐	☐	☐	☐
Timescale	14. The use-time of the building/structure is the same as planned in the design brief.	☐	☐	☐	☐	☐
	15. The time for deployment is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
	16. The time for dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
	17. The time for transportation after dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☐	☐
Aesthetics	18. The scale of the building/structure is aesthetically appropriate.	☐	☐	☐	☐	☐
	19. The building's structure is aesthetically suitable.	☐	☐	☐	☐	☐
	20. The selection of the construction material is appropriate.	☐	☐	☐	☐	☐
	21. The colour of the building/structure is appropriate and appreciated by its users.	☐	☐	☐	☐	☐
	22. There is adequate daylight in the building.	☐	☐	☐	☐	☐
	23. The artificial lighting levels in the building/structure are satisfactory.	☐	☐	☐	☐	☐
	24. The building/structure produces a low number of complaints/faults reported by users.	☐	☐	☐	☐	☐
	25. The owner of the site is pleased with the building/structure.	☐	☐	☐	☐	☐

APPENDIX D

Questionnaires – UK Premiere of the 'Exxopolis' Luminarium

Please tick in the □

1	Gender	□ Male □ Female
2	Age group	□ Under 18 □ 18-30 □ 31-40 □ 41-50 □ 51 or older
3	Do you have any architectural/art training experience?	□ I have had professional architectural/arts training experience. □ I am not professionally trained, but I have always been interested in architecture and art. □ I do not have any related training experience.
4	Where did you hear about the Exxopolis Luminarium?	□ Word of mouth □ I read about it on the Architects of Air's website. □ I read about it on the Lakeside's website. □ I read about it from other media/press. □ Others, please clarify here:_____________
5	From where did you travel to Nottingham?	□ Overseas □ I am local. □ Other parts of England □ Wales □ Scotland □ Northern Ireland
6	Did you find the festival site easily?	□ I found the site easily. □ It took me a little while to find the site. □ I didn't find the site easily.
7	Have you visited a Luminarium before?	□ Yes, I have visited the Luminarium at______ (location) in _______ (year). □ No, this is my first time visit
8	Did you attend the festival and discover the Luminarium onsite or did you come especially for the Luminarium?	□ I came especially for the festival. □ I came especially for the Luminarium. □ I came for both of the festival and the Luminarium.
9	How long did you stay inside the structure?	□ less than 15 minutes □ between 15 – 30 minutes □ between 30 minutes – 1 hour □ longer than 1 hour
10	Do you think there was enough lighting inside the structure?	□ Yes, there was ample lighting for me. □ No, there wasn't enough lighting for me inside.

11	What do you think of the colours inside the structure?	□ The colours are beautiful! □ I am not sure. □ The colours are not beautiful.
12	Did you feel crowded inside the structure?	□ I felt crowded inside the structure. □ I didn't notice whether it was crowded or not. □ I didn't feel crowded inside the structure.
13	Did you feel relaxed and calm inside the structure?	□ Yes, I felt rather relaxed and calm. □ I am not sure. □ No, I didn't feel relaxed and calm.
14	Did you find the structure exit easily?	□ I found the exit easily. □ It took me a little while to find the exit. □ I had to ask someone where the exit was.
15	How much did you enjoy your visit?	□ I had an enjoyable experience today! □ I am not sure. □ I didn't have an enjoyable experience today.
16	If you enjoyed your visit, what did you find most exciting?	□ The festival. □ The Luminarium. □ I found both of the festival and the Luminarium exciting.
17	Would you like to come to see the Luminarium again and recommend it to your family and friends?	□ Yes □ Maybe □ No

Comments:

Questionnaires Results – UK Premiere of the 'Exxopolis' Luminarium

	Number of visitors	Number of questionnaires	Total
02/06/2012	798 + 79 comps	408 + 49 comps	1141
03/06/2012	117	93	210
Percentage (%)	14.8	26.3	18.4

Selected comments from the visitors:

Visitor 1 "you should make the sides stronger so you can rest on them & have a section for calmness and a section for running, and have it bigger and more variety of colours"

Visitor 2 "the blue (colour) is too dark for the children"

Visitor 3 "maybe you can have different music for different colours (domes)"

Visitor 4 "the floor was too bumpy for me, I thought about bringing a pair of soft shoes that I wear on the wooden floors"

Visitor 5 "my son from Northampton told me about this, it was not in the Nottingham Evening Post (local news)"

Visitor 6 "There were too many children running around"

Visitor 7 "I visited the Luminarium in 2005 in Budapest (Amozozo) and I didn't know about the Exxopolis this year. I saw it when we came for the theatre"

Visitor 8 "it was freezing"

Exxopolis Evaluation Questionnaires Comments – Completed by Alan Parkinson on 1 December 2012

	Indicators	Comments
Function	01 Thermal comfort quality	Heat gain is considerable – when used in temperate conditions heat is not an issue. It is considerably easier to heat the structures than to cool them.
	02 Acoustic quality	Acoustic quality is not a primary consideration – there are pluses and minuses – inflatable volumes can generate interesting resonances. The thinness of the walls means that proximity to load sound outside can disrupt the calm inside.
	03 Spatial comfort quality	I'm not sure our structures are small scale – I think they're optimum size for visitor comfort.
	04 The design for disabled users	The origins of the project meant that disabled users were a primary consideration in terms of ease of access to the structure.
	05 Circulation space	The journey for the visitor is an essential part of the experience so is well defined.
	06 Furniture arrangement	Purposely without furniture.
	07 Storage consideration	Storage is not a consideration.
	08 Usability	The functionality of the structure centres of the usability of the space – so it is convenient.
	09 Maintainability	Our PVC structures are well built – but are delicate and vulnerable to damage – they are however easy to repair and maintain.
Finance	10 Construction preparation	Difficult to answer these questions re "appropriate" in relation to cost – what would it mean if the costs were inappropriate?
	11 Physical plant	N/A
	12 Administrative service cost	N/A
	13 Waste management	N/A
	14 Dismantling cost	N/A
	15 The cost of transportation and storage	N/A
Timescale	16 Operation time	The lifespan of a structure is variable for reasons we don't understand but could be allied to a mix of UV exposure and pollution exposure. Using the same materials some of our structures may be presentable after 250 days of exhibition and others we may decommission after 150 days.
	17 Deployment time	As we've been mounting similar structures for 25 years we know how long one should take to set up. What may hinder the planned time being met could be the weather, poor technical support, lack of staff.
	18 Dismantling time	As we've been mounting similar structures for 25 years we know how long one should take to set up. What may hinder the planned time being met could be the weather, poor technical support, lack of staff.
	19 Transportation time	Transportation is in the hands of freight companies - it nearly always goes to plan.
Aesthetics	20 Scale	The scale of the structure is rarely considered in relation to a site as these are itinerant structures. They are perfectly considered in relation to the scale of the visitors.
	21 Structure	The structure is pretty efficient – it is primarily conceived to be seen from the inside and in that respect it is aesthetically suitable. From the outside I'd say it is less aesthetically suitable – it looks more like a play structure.
	22 Material	The aesthetic of the structure could only be achieved with materials I use – so they are perfectly suitable.
	23 Colour of the building/structure	The colour is indivisibly part of the structure.
	24 Illumination (daylight)	The daylight is also an indivisible part of the intention of the structure and its degree of penetration is finely calculated.

	25	Illumination (artificial lighting)	We do use it but it can't achieve the aesthetic of daylight.
	26	Acceptability to the users	Up to 3000 visitors a day passing through the structure and most of them coming out with a sense of well-being is an indicator of how well the design is accepted.
	27	Appropriateness of the building site	Positioning is collaboration with the presenter/ client to ensure optimum visibility and ideal usability for the public.

Exxopolis Evaluation Questionnaires – Completed by Alan Parkinson on 27 November 2012

Design Quality Indicators of Small-Scale Public Demountable Buildings (Post-Occupancy Evaluation)						
Instructions	The Conceptual Evaluation Model was developed by Junjie Xi as a part of the research results in the evaluation of small-scale public demountable buildings. There are 27 indicators in the model. Please select the checkbox that you feel is most suitable for your design. Please only select one option for each indicator.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
	Performance Indicators	**1**	**2**	**3**	**4**	**5**
Function	1. The thermal comfort quality (temperature and humidity) is appropriate for its use.	☐	☒	☐	☐	☐
	2. The acoustic quality is appropriate for its use.	☐	☐	☐	☒	☐
	3. The spatial comfort quality is appropriate for its use.	☐	☐	☐	☐	☒
	4. The design for disabled users is well planned.	☐	☐	☐	☐	☒
	5. There is circulation space left for the emergency exit.	☐	☐	☐	☒	☐
	6. The furniture can be well arranged inside the building.	☐	☐	☒	☐	☐
	7. The storage is well considered.	☐	☐	☒	☐	☐
	8. It is convenient for the promoters/clients to use the building/structure.	☐	☐	☐	☐	☒
	9. The building/structure will weather well and can be easily maintained.	☐	☐	☐	☒	☐
Finance	10. The final cost of the construction materials, building machinery and tools is appropriate for the budget.	☐	☐	☐	☒	☐
	11. The final cost of the physical plant is appropriate.	☐	☐	☐	☒	☐
	12. The final cost of administrative services is appropriate.	☐	☐	☐	☒	☐
	13. The final cost of disposing of waste building/structure materials is appropriate.	☐	☐	☐	☒	☐
	14. The final cost of dismantling is/will be appropriate.	☐	☐	☐	☒	☐
	15. The final cost of transportation after dismantling will be appropriate.	☐	☐	☐	☒	☐
Timescale	16. The use-time of the building/structure is the same as planned in the design brief.	☐	☐	☒	☐	☐
	17. The time for deployment is/will be the same as planned in the design brief.	☐	☐	☐	☐	☒
	18. The time for dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☐	☒
	19. The time for transportation after dismantling is/will be the same as planned in the design brief.	☐	☐	☐	☒	☐
Aesthetics	20. The scale of the building/structure is aesthetically appropriate.	☐	☐	☐	☐	☒
	21. The building's structure is aesthetically suitable.	☐	☐	☐	☐	☒
	22. The selection of the construction material is appropriate.	☐	☐	☐	☐	☒
	23. The colour of the building/structure is appropriate and appreciated by its users.	☐	☐	☐	☐	☒
	24. There is adequate daylight in the building.	☐	☐	☐	☐	☒
	25. The artificial lighting levels in the building/structure are satisfactory.	☐	☒	☐	☐	☐
	26. The building/structure produces a low number of complaints/faults reported by users.	☐	☐	☐	☒	☐
	27. The owner of the site is pleased with the building/structure.	☐	☐	☐	☐	☒

APPENDIX E

Kreod Evaluation Questionnaires Comments – Completed by Chunqing Li on 17 December 2012

	Indicators		Description
Function	01	Thermal comfort quality	N/A
	02	Acoustic quality	Very good (see serge Ferrari's product data for further information)
	03	Spatial comfort quality	Evaluates whether small-scale projects offer good spatial comfort quality to the building users.
	04	The design for disabled users	A ramp is available for disable access.
	05	Circulation space	Evaluates whether the circulation space was well designed.
	06	Furniture arrangement	KREOD is a very flexible space for seminars, exhibitions and events.
	07	Storage consideration	N/A
	08	Usability	KREOD was designed as a dynamic, functional exhibition/event space. The structure could be dissembled and reassembled or transported to different site with a lorry.
	09	Maintainability	The Kebony timber structure is malignance free, steelwork needs to be repainted from time to time; The tensile fabric to be cleaned with soapy water.
Finance	10	Construction preparation	Apart from fabricator's CNC machine broke down, everything else went well.
	11	Physical plant	The KREOD was highly collaborative and the mostly sponsored by a range of companies and was built by volunteers. The overall cash flow was designed and monitored by the director and the financial control.
	12	Administrative service cost	Administrative work was done by the director and the financial control.
	13	Waste management	All wasted timber, error and cracked components were used as renewable energy source - burned in the CHP (Combined Heat and Power) machine to generate heat, hot water and electricity.
	14	Dismantling cost	N/A (it's not been done yet)
	15	The cost of transportation and storage	The timber components are flat packed which were transported by a transit van. Tensile by a van and steel structure by a lorry.
Timescale	16	Operation time	The completion was later than expected due to the fabricator's CNC machine broke down.
	17	Deployment time	The KREOD project was based on good will and everything was uncertain and the plan didn't make any sense without the sponsorship.
	18	Dismantling time	N/A (it's not been done yet)
	19	Transportation time	N/A (it's not been done yet)
Aesthetics	20	Scale	The scale of KREOD is small and prefabricated; it could be built on site.
	21	Structure	KREOD has got reciprocal connection detail, not only structurally efficient but also visually aesthetic.
	22	Material	The material for the structure was Kebony, it's a sustainable alternative to tropical hardwood and preservative treated wood – the wooden structure of KREOD is durable, resistant, sustainable, environmentally-friendly, easily-maintained and beautifully aesthetic.
	23	Colour of the building/structure	The colour of the structure is brown, the natural colour of Kebony timber. Evaluates the appearance of the building/structure from both internal and external view.
	24	Illumination (daylight)	The membrane beneath the structure is translucent and the natural daylight can penetrate through.
	25	Illumination (artificial lighting)	The artificial light is Targeti Poulsen's low energy RGB LED lighting. Unfortunately it wasn't installed as the

			subcontractor was disappeared.
	26	Acceptability to the users	Excellent: Functions & beautifully.
	27	Appropriateness of the building site	KREOD is a mobile structure and non-site specific

Kreod Evaluation Questionnaires – Completed by Chunqing Li on 17 December 2012

Design Quality Indicators of Small-Scale Public Demountable Buildings (Post-Occupancy Evaluation)						
Instructions	The Conceptual Evaluation Model was developed by Junjie Xi as a part of the research results in the evaluation of small-scale public demountable buildings. There are 27 indicators in the model. Please select the checkbox that you feel is most suitable for your design. Please only select one option for each indicator.	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
	Performance Indicators	**1**	**2**	**3**	**4**	**5**
Function	1. The thermal comfort quality (temperature and humidity) is appropriate for its use.	☐	☐	■	☐	☐
	2. The acoustic quality is appropriate for its use.	☐	☐	☐	■	☐
	3. The spatial comfort quality is appropriate for its use.	☐	☐	☐	■	☐
	4. The design for disabled users is well planned.	☐	☐	☐	■	☐
	5. There is circulation space left for the emergency exit.	☐	☐	☐	■	☐
	6. The furniture can be well arranged inside the building.	☐	☐	☐	■	☐
	7. The storage is well considered.	☐	☐	■	☐	☐
	8. It is convenient for the promoters/clients to use the building/structure.	☐	☐	☐	■	☐
	9. The building/structure will weather well and can be easily maintained.	☐	☐	☐	☐	■
Finance	10. The final cost of the construction materials, building machinery and tools is appropriate for the budget.	☐	☐	☐	☐	■
	11. The final cost of the physical plant is appropriate.	☐	☐	☐	■	☐
	12. The final cost of administrative services is appropriate.	☐	☐	☐	☐	■
	13. The final cost of disposing of waste building/structure materials is appropriate.	☐	☐	☐	☐	■
	14. The final cost of dismantling is/will be appropriate.	☐	☐	☐	■	☐
	15. The final cost of transportation after dismantling will be appropriate.	☐	☐	☐	■	☐
Timescale	16. The use-time of the building/structure is the same as planned in the design brief.	☐	☐	■	☐	☐
	17. The time for deployment is/will be the same as planned in the design brief.	☐	☐	■	☐	☐
	18. The time for dismantling is/will be the same as planned in the design brief.	☐	☐	☐	■	☐
	19. The time for transportation after dismantling is/will be the same as planned in the design brief.	☐	☐	☐	■	☐
Aesthetics	20. The scale of the building/structure is aesthetically appropriate.	☐	☐	☐	☐	■
	21. The building's structure is aesthetically suitable.	☐	☐	☐	☐	■
	22. The selection of the construction material is appropriate.	☐	☐	☐	☐	■
	23. The colour of the building/structure is appropriate and appreciated by its users.	☐	☐	☐	☐	■
	24. There is adequate daylight in the building.	☐	☐	☐	☐	■
	25. The artificial lighting levels in the building/structure are satisfactory.	☐	☐	■	☐	☐
	26. The building/structure produces a low number of complaints/faults reported by users.	☐	☐	■	☐	☐
	27. The owner of the site is pleased with the building/structure.	☐	☐	☐	☐	■

Kreod Evaluation Questionnaires – Completed by Jan Terje Nielsen on 2 April 2013

Design Quality Indicators of Small-Scale Public Demountable Buildings (Post-Occupancy Evaluation)						
Instructions	The Conceptual Evaluation Model was developed by Junjie Xi as a part of the research results in the evaluation of small-scale public demountable buildings. There are 27 indicators in the model. Please select the checkbox that you feel is most suitable for your design. Please only select one option for each indicator.	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
	Performance Indicators	**1**	**2**	**3**	**4**	**5**
Function	1. The thermal comfort quality (temperature and humidity) is appropriate for its use.	☐	☐	☐	☒	☐
	2. The acoustic quality is appropriate for its use.	☐	☐	☐	☐	☒
	3. The spatial comfort quality is appropriate for its use.	☐	☐	☐	☒	☐
	4. The design for disabled users is well planned.	☐	☒	☐	☐	☐
	5. There is circulation space left for the emergency exit.	☐	☐	☐	☐	☒
	6. The furniture can be well arranged inside the building.	☐	☐	☐	☒	☐
	7. The storage is well considered.	☐	☐	☒	☐	☐
	8. It is convenient for the promoters/clients to use the building/structure.	☐	☐	☐	☐	☒
	9. The building/structure will weather well and can be easily maintained.	☐	☐	☐	☐	☒
Finance	10. The final cost of the construction materials, building machinery and tools is appropriate for the budget.	☐	☐	☐	☐	☒
	11. The final cost of the physical plant is appropriate.	☐	☐	☐	☐	☒
	12. The final cost of administrative services is appropriate.	☐	☐	☐	☐	☒
	13. The final cost of disposing of waste building/structure materials is appropriate.	☐	☐	☒	☐	☐
	14. The final cost of dismantling is/will be appropriate.	☐	☐	☐	☒	☐
	15. The final cost of transportation after dismantling will be appropriate.	☐	☐	☐	☒	☐
Timescale	16. The use-time of the building/structure is the same as planned in the design brief.	☐	☐	☒	☐	☐
	17. The time for deployment is/will be the same as planned in the design brief.	☐	☐	☒	☐	☐
	18. The time for dismantling is/will be the same as planned in the design brief.	☐	☐	☒	☐	☐
	19. The time for transportation after dismantling is/will be the same as planned in the design brief.	☐	☐	☒	☐	☐
Aesthetics	20. The scale of the building/structure is aesthetically appropriate.	☐	☐	☐	☐	☒
	21. The building's structure is aesthetically suitable.	☐	☐	☐	☐	☒
	22. The selection of the construction material is appropriate.	☐	☐	☐	☐	☒
	23. The colour of the building/structure is appropriate and appreciated by its users.	☐	☐	☐	☐	☒
	24. There is adequate daylight in the building.	☐	☐	☐	☐	☒
	25. The artificial lighting levels in the building/structure are satisfactory.	☐	☐	☒	☐	☐
	26. The building/structure produces a low number of complaints/faults reported by users.	☐	☐	☐	☐	☒
	27. The owner of the site is pleased with the building/structure.	☐	☐	☐	☐	☒

APPENDIX F

List of Conference Contributions

- Xi J (2013), Evaluating the Functional Performance of Small-Scale Public Demountable Buildings. At: The International Conference on Adaptation and Movement, 2013, Toronto, Canada

- Xi J (2013), The Value of Demountable Buildings in Urban Studies. At: The 20th International Seminar on Urban Form, 2013, Brisbane, Australia

- Xi J (2013), The Value of Demountable Buildings. At: The 7th International Association for China Planning (IACP), 2013, Shanghai, China

- Xi J (2012), Evaluating the Functional Performance in Small-Scale Public Demountable Buildings. At: DMI 2012 International Research Conference, 2012, Boston, USA

- Xi J (2011), Evaluation Methodology for Adaptive Architecture. At: Inhabiting Adaptive Architecture Workshop, following Adaptive Architecture International Conference 2011, London, UK

- Xi J (2010), The Evaluation of Temporary and Demountable Architecture as Post-Earthquake Shelter Solutions. At: Oxford Brookes University Shelter Conference 2010, Oxford, UK

- Xi J & Stevenson C (2010), The Evaluation of Temporary and Demountable Architecture as Post-Earthquake Shelter Solutions. At: IASS (International Association for Shell and Spatial Structure) 2010 Shanghai "Spatial Structures – Temporary and Permanent", Shanghai, China