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Kit-of-parts Structures in an Urban Context:
A GREEN APPROACH TO THE DESIGN OF EVENTS BUILDINGS

Sihao Shen

A thesis submitted in fulfillment of the requirements for the degree of
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2013
The work described in this dissertation was mainly carried out at the School of Architecture and Planning of the University of Auckland between June 2007 and June 2011. This dissertation would not have been possible without the guidance and help of several individuals who in one way or another made a contribution. Their valuable assistance in the preparation and completion of this study is much appreciated.

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ABSTRACT

As urbanisation and population growth put increasingly more pressure on an already limited supply of urban land, leading to a declining living environment, there is evidence that international expositions, including the Olympic Games, have been part of an inescapable process in the forming of world class cities. On the other hand, many people have pointed out that the waste generated by these mega-events is one of the factors causing urban environmental deterioration. The aim of this research is to investigate and find out whether most of the current permanent mega-event buildings could be replaced with more adaptable systems, which could greatly reduce the wastage of precious natural resources and help solve the problem of under utilisation after large scale events have concluded.

Generally, this research adopts a case study approach. Despite most of these instances coming from China, they are criticized and associated with a global perspective. Following the process of observation, comparison and analysis, investigations into major global event sites are conducted. As a potential role model for adaptable non-permanent events buildings the thesis undertakes an extensive study of a particular vernacular temporary exhibition building, the Black Yak Hair Tent (BYHT). This work has involved field visits and examination of historical records, as well as interviewing those currently producing and caring for such tents. Having survived extremely adverse environmental conditions, such as serious earthquakes, some ancient Chinese timber buildings also serve as examples illustrating and contributing to the argument for the feasibility of the kit-of-parts approach to design.

In addition, a survey of professionals involved with major exhibitions and of the public was conducted which revealed that people are concerned about short lived events buildings, and are also increasingly in favour of a new type of temporary exhibition building. The case studies in this research do suggest that temporary exhibition buildings are achievable, especially when approached through making use of the reciprocal principles of the whole structure, and that these need to be combined with flexible use of public space in urban environments. It has also been argued that the kit-of-parts approach is the path to achieving these goals, while at the same time ensuring that not all temporary structures will have the same form. Such buildings will thus have a greater chance of being aesthetically acceptable to the users.

For best reflecting the conflicts between rapid urbanization and the ecological and environmental impact caused by mega-event buildings, the interactions from the perspectives of city, urban events and event buildings have been selected as points of penetration in this thesis. The conclusions of this research are that the modern method of event building procurement is not sustainable or compatible with today’s urban realities, and that new methods of event building design based on a multidiscipline design approach of Hybridizing Kit-of-parts Structure (HKS) can be developed.
Fig. 1-1. The Once Flourishing Age, gouache

Hereafter, all drawings, tables and photographs are by the author unless otherwise noted.
As represented by Expos, the Olympic Games, and other large conventions and exhibitions, mega events have become an important means to enhance and improve a city’s competitiveness. Big events and accompanying events buildings or superstructures also profoundly affect and change the city, life within it and its future development. As the main space for big city event activities, events buildings can be defined as the construction of a large building or group of buildings that directly serve certain public activities, and which are mostly constructed and financed by city government or public funding.

Just as a name conjures up an image of the person, events buildings can become the most vivid symbol of a major event. The level of technological development in an era is often mapped in the construction of the big event. Comparing the host city to a stage, the mega event becomes a thrilling and unending drama and event buildings are stage sets. By virtue of these cleverly designed and well-made sets, mega events can make high drama, but drama is a fleeting rather than a lasting art. The buildings of many old event venues remain empty or have disappeared, although the names and images of these buildings are still alive. However, other big events have left a wealth of resources related to human construction science and cultural heritage, or have become local landmarks (Fig. 1-1).

Regardless of how advanced the economy and technology are, the nature of people is to celebrate and some common festivals are always needed. Also the progress of culture and arts, and science and technology requires the greatest degree of communication and cooperation. The big event is the best reason for all mankind to come together and holding a big event has its own rationality and inevitability.

As time passes, the forms of a big event with its buildings should have different attributes in different ages. Mega events were once dominated by a few big powers, such as the USA and some European countries, but more developing countries are now holding them. The contents of display range from single products and national strengths to competitive sports. However, with advances in transportation and communication, and the rise of new types of technology and industry, the big event is facing a time of repositioning. More importantly, under today’s globalization, cities and the environment have never been faced with so many common problems and challenges as they are today, and this must have an effect on the events industry. There is reason to suspect that the city, an event and its building
can coexist and prosper under today’s circumstance. If the modern event is seen as an episode in the serial drama of city development, then what are the episodes that come after? How does having an event influence other episodes in the urban story? Can the relationship between the event and the city become a two way transaction? These are the unanswered questions that have led to this research.

1-1 The Hypothesis and Research Questions
Driven by uncertain interests, although the host cities of mega events usually lose money, many cities still crave to be hosts, even though this often eventually worsens an already difficult situation. Holding this kind of event has its rationality and seems inevitable, but, as part of normal urban development, the conventional approach to event building procurement is not sustainable, as well as not being compatible with the fast growing urban realities as these relate to frequent changes in building function. The hypothesis in this thesis is that a hybridized kit-of-parts approach to events buildings based on the 3Rs (reduce, reuse, recycle) will be a more sustainable, feasible and technically correct solution.

Such a hypothesis in turn raises the following questions:

- In the current situation, what are the ideal forms of events buildings from the viewpoint of urban sustainable development?
- What are the historical lessons provided by earlier events buildings?
- As a building type designed for repeated assembly and disassembly, does the Kit of Parts (KOP) approach have the technical assurance and aesthetic requirements to suit current urban realities?
- Given that the Black Yak Hair Tent (BYHT) is a portable and reusable events building (and hence an example of KOP) that is the product of appropriate technology, what kind of inspiration can urban events buildings draw from this precedent?

1-2 Why Study These Issues
It is generally believed that large international events work as triggers for local development and bring tangible advantages to the host city and country. Amongst their tangible benefits, mega-events are catalysts for economic transformation, help upgrade urban infrastructure, strengthen the international
image of the city and accelerate the implementation of desired urban policies. However, just like everything in the world, all of these developments are open to both benign and malign interpretations. Major events can often change a city in many inconceivable ways. An example is land prices. At the time of attracting huge investment and constructing ornate events buildings, the prices of land and housing can be pushed up, forcing city residents to move. The main body of the city - the people - is threatened, leading to a series of social contradictions.

As early as 1972, a report put forward questions and warnings about the unforeseen effects of large scale development. Not realizing that resources are finite and using constructing methods for temporary buildings that are more appropriate to permanent buildings will eventually exhaust non-renewable resources and stall human development. In addition, construction wastes from short term buildings add to an existing waste problem that will eventually destroy the environment in which human beings live. The 1972 report indicates that the crisis of diminishing global resources and a polluted environment will be faced in the middle of the 21st century. Forty years have passed, and this environmental crisis has barely been addressed. Adding insult to injury, mega-events buildings are taxing the earth’s ability to supply necessary support for human living.

1-2-1 The growing risk from Construction and Demolition (C&D) waste in cities
C&D waste is the most immediate and tangible side-product of construction activities especially when a city is hosting big events, and can do great damage to the environment. Such damage includes the occupation of land, pollution of water bodies, atmospheric pollution, soil pollution, and waste of potentially scarce resources.

Construction waste refers to broken bricks, concrete, mortar, packaging materials, mud and other rubbish that occurs through renovating, rebuilding, expanding, maintaining, and demolishing all types of buildings. According to China Daily:

- In China, construction waste comprises 30 to 40 percent of the total urban waste;

- The construction of a 10,000-sq-m building will create 500 to 600 tons of waste, while the demolition of an 10,000-sq-m old building will create 7,000 to 12,000 tons of waste, according to industrial data:
- Space from building demolition in China annually constitutes about 40 percent of the total construction area.³

As the largest country in terms of scale of construction in the world, and considering the fact that there are so many projects now under construction in China, the quantities of C&D waste are vast.

So how exactly can such large scale rubbish be dealt with? There is no way for the builder to deal with building rubbish effectively through formal channels of materials recovery due to the limited capacity of these as designated by government. According to Chen Jialong, Professor of Beijing Construction Engineering College “The recent waste recovery rate is less than 5%, and the rest is mainly disposed of by landfill disposal.”⁴ However, only about 10% of the construction waste will be transported to the designated disposal areas, and the rest is dumped or delivered to illegal landfill places in most cities. This shocking data was discovered by Dr. Gao, Shiyang of the Department of Geography at the University of California, Berkeley, based on a one-year construction waste recycling rate investigation in Beijing. “Right now, Beijing designated construction waste elimination points are mainly distributed in the outer suburbs, and where dumping waste needs a dumping sediment transport card and consumer satisfaction certificate, as well as fees and transportation costs” Gao stated, making the process both difficult and expensive, “Some even take advantage of the night dumping directly on both sides of the major highways.”⁵ The same study found the recycling rate to be less than 40% for the 40 million tons of all rubbish produced in Beijing annually.

The biggest problem in the disposal of construction waste is that it occupies a lot of land: ten thousand tons of construction waste occupies 2.5 Mu⁶ (0.16 hectare), according to the calculation of Chen, Jialong.⁷ Thus in the next 20 years, China's growth in construction waste will enter a peak period,

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³ Wang, Qian, Short-lived buildings create huge waste, updated: 2010-04-06, Beijing: China Daily (English)
⁵ Text proper in Chinese: 林衍，建筑垃圾正在吞噬我们的城市，2010 年 05 月 12 日,来源:《中国青年报》
⁶ Chinese: 亩 or 畝 is a Chinese unit of area. A hectare is equal to 15 Mu
which will intensify the people and land conflicts that have already appeared in the process of urbanization.

In addition, some organic materials can decompose and produce harmful gases in the process of being stack-piled, which can pollute the atmosphere. Some experts have pointed out that glue, paint, and other construction waste contains harmful heavy metal elements. The rubbish buried under the ground will cause groundwater contamination. At least 5 billion tons of newly created construction waste will occur when 30 billion square metres of residential buildings are set up in 2020, according to the latest city plan released by the Ministry of Construction.

The damage caused by construction waste mainly concerns three aspects:

1) A large land area is occupied. In the case of Beijing, 20 to 30 construction waste elimination fields will need to be set every year to meet the need of housing waste from demolition of the original Olympics building and other new construction, causing big pressure on land availability.

2) Serious environmental pollution is caused. Materials like rubber, dope and paint inside construction waste are not only difficult to biodegrade, but also contain harmful heavy metal elements. These wastes when buried in the ground will cause groundwater contamination and could directly harm the surrounding residents.

3) The soil structure is destroyed, causing surface subsidence. Landfill today has to be finished with 2m level earth on 8m waste-filled land. However the soil on top of the waste is difficult to re-vegetate. It takes quite a long time to reach a steady state as the landfill area will undergo a settlement and subsidence period.

What the government worries about most is how to deal with the 5 billion tons of newly created construction waste projected to be created by 2020. Based on an international estimation, each million tons of construction waste takes up to 1 acre of landfill land, which then means up to 10 million acres for construction rubbish land filling. Urbanization is a process of external expansion, but the effect of this entire waste is that soon construction costs will be greatly increased when buildings have

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9Ditto.

10Text proper in Chinese: 郑向鹏，专家提出综合利用建筑垃圾十大举措，建设工程选材指南 2007 年 4 月第 4 期
be built on the land with filled waste underneath, which will make for difficult and expensive foundations, or need removal of the waste to yet another site.

Taking Beijing as an example, daily garbage was about 18,300 tons and annual output was 6.69 million tons in 2009, and 90% of this went to land fill, which can take up to 500 acres of land every year, meaning there are now 17 waste disposal sites in Beijing. However, 10 waste disposal facilities will be shut down in succession this year and then about 10,770 tons of garbage will have nowhere to go, but will still be piling up every day in Beijing.\textsuperscript{11} Next year, waste disposal stations will be set up in Chaoyang, Haidian, Changping, and Daxing District and then the city's annual construction waste disposal capacity will reach 400 million tons. Currently, annual construction waste is about 35 million tons, with 10 million tons produced in six districts, including 2 million tons of residential garbage.

According to statistics, 40 million tons of construction waste were produced annually during the Olympic Games preparation period and 20 million after; 20 million annually were produced during the Shanghai Expo preparation period; 750 tons annually came from the construction of the subway and old town transformation; and 10 million tons and 14 million cubic metres are produced annually in Shenzhen and Guangzhou. This waste is basically in a disorderly management state in China.\textsuperscript{12}

With the continued outward expansion of the city, waste disposal facilities continue to expand outside the Fourth Ring, and even as far away as Hebei and other places. Some landfills have been changed into green spaces, and some have even been used for the construction of limited two storey housing. Some landfill areas and glamorous high-rise buildings are only separated by a wall. For example, within a radius of 700 metres of the landfill site in Fengtai is a famous headquarters base and world-park, surrounded by more than a dozen residential districts and more than ten villages, involving a population of more than seventy thousand people.\textsuperscript{13}

Landfill sites around Beijing were planned and designed in the 1990s, and the standard of siting, treatment processes and technologies is more than a decade old. A lot of harmful construction waste was simply buried since they were set up. In Daxing District vegetable fields surround the transfer station in which vegetables need watering from underground water that is being contaminated by rubbish; meanwhile cows drink contaminated water from the river and flocks of sheep look for food in

\textsuperscript{11} Text proper in Chinese: 唐黎明: 北京，城市与垃圾之战将上演，2010年06月18日，中国经营网

\textsuperscript{12} Ibid.

\textsuperscript{13} Ibid.
the garbage field. Not only do the dioxins produced through garbage incineration cause health hazards but also the pollution caused by landfill has penetrated into daily lives through a variety of channels.

In the past two years, the annual emissions of all types of building rubbish in Guangzhou have amounted to nearly 12 million cubic metres, according to Guangzhou Sanitation Bureau Mud Treatment Department which discharges the mud and sediment resulting from construction.\textsuperscript{14} Until the middle of last month, Guangzhou produced 5.68 million cubic metres of construction waste this year, and Chen Sihua, section chief at Guangzhou Sanitation Bureau, expects that Guangzhou will enter a construction waste peak period with the starting of the metro, new railway station and the Asian Games venues. How to deal with this waste is becoming a major problem for the government with the fast development of Guangzhou. Therefore, the Guangzhou government has put construction waste storage on the agenda. As total capacity of 15.16 million cubic metres of large-scale construction waste receiving fields is planned, occupying 460 acres that can deal with 10,000 cubic metres waste, and these will be built at Longgui Zhenyong Village, in the Baiyun District.

The change in construction waste production in terms of quantity and type of components connects closely with city development and constructing methods. According to official statistics, during 2001-2006 the annual construction waste in Shanghai was around 18 million tons. In 2007 this rose sharply to 30.65 million tons and up to 35 and 40 million tons in the years 2008 and 2009. By 2010 there were 84 major projects underway in Shanghai and construction waste was declared to be more than 46 million tons.\textsuperscript{15} Not only was 2007 the start of the Expo construction boom in Shanghai, but a new upsurge in construction was also started. So, the statistics of Shanghai indirectly reflect the dramatic increase in waste due to holding a mega event, just as happened with the Beijing Olympics in 2008. In Shanghai four waste disposal facilities covering 550 Mu (36.66 hectares) are planned to be set up before 2015, to deal with 4600 tons of waste per day, following the principle of each suburban district having its own facility.

Differing from the Aichi Expo in Japan which was located in the Expo Park in the outskirts of the city, Shanghai Expo was set up on an area of old buildings, which meant a great number of original

\textsuperscript{14}Text proper in Chinese: 汤璇等, 建筑垃圾循环利用的新契机广东建设报 2005-06-07
buildings had to be removed along with the Expo construction waste. The first problem was that the transportation infrastructure was scarcely sufficient to ship all the construction waste from the site; daytime transportation could overwhelm Shanghai’s existing traffic and the noise caused at night could affect residents’ normal rest badly, along with huge energy consumption and transportation emissions problems. However, related problems were far more difficult to solve as it was never easy to find the necessary large landfill area at a time when land resources were becoming increasingly strained.

The total amount of C&D waste produced by Shanghai Expo can be seen in the following examples. The existing area of 3.2 million square meters that had to be demolished area contained 13 large companies and a small number of residents. A specialist from Tongji University estimated that the demolition waste could be 2.9 million tons in total according to the function, style, structure and age of the old buildings. This is an alarming figure for a mega event because the annual construction waste in Shanghai was around 18 million tons before 2007.

Natural plant cover is also reducing in Chinese cities, and with this a variety of environmental functions of urban green space is gradually being lost. Urban green space is an important part of the urban ecosystem, which normally consists of three parts: suburban farmland, suburban natural vegetation cover and urban garden green space. Losing parts of this could have an irreplaceable effect on city development and residents’ lives. However, the natural environment around cities is also being utilized as the site for factories, dwellings, roads, plazas, and even orchards and vegetable gardens. Natural plant cover is being cleared and replaced by a dense cover of people and buildings. In addition, a large amount of cultivated land is also lost. Between 1981 and 1985 100 million mu have been lost every year during. From the 1950s net annual decrease in field area has been 48 million Mu on average. After the 1990s, the national annual reduction was about 500 million mu, and in the case of Beijing, the land used to accommodate construction waste is up to 3000 mu per year. 18.5 million tons of construction waste were created by the big Kobe earthquake in Japan. Based on the calculation of construction waste produced, Beijing has an equivalent big earthquake like this every year.

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17 Text proper in Chinese: 杨靖;闫荣馨;浅谈城市环境问题及对策研究，《北方环境》2011年第04期
18 Text proper in Chinese: 记者文静, 北京建筑垃圾填埋一年吃掉3000亩地, 2011年01月28日, 京华时报
In recent years, the annual built construction area in China is 16 to 20 billion cubic metres, more than the sum of all construction in developed countries. In accordance with 500 to 600 tons of waste from every new 10,000m² construction in developed countries, the annual sum of produced and discharged construction waste is between 0.8 and 1.2 million tons. On the other hand, 1700-2000kg of sand is needed to produce every 1m³ concrete, and in 2004 the national concrete output was around 2.84 hundred million cubic metres, so the consumed gravel and aggregate was 4.8 to 5.7 million tons.²⁰ Such a huge amount of C&D waste output and gravel aggregate demand will inevitably lead to huge rubbish dumps and quarrying, which can result in serious destruction of the ecological environment. How to deal with and dispose of construction waste has become an important issue for the construction industry along with the promulgation and implementation of laws to protect cultivated land and the natural environment.

If these situations of C&D are the consequences of the boom in both construction and mega-events in China, which could be seen as an abnormal condition, it is useful to examine data under ordinary conditions in America. Affected by the recent global crisis, construction in the United States continues to be sluggish, however, the EPA once estimated that 136 million tons of building-related C&D waste was generated in the US and there were close to 1900 construction and demolition landfills in 1994.²¹ Even ignoring the health influences caused by C&D waste, the cost of labor and landfills is already a large expenditure, and the alternative disposal systems are not much better. For example, wood debris that was once loaded into skips by the solid waste management and sorting company of Norcal Waste Systems, Inc. in San Francisco California, now has to be cut into small pieces of wood about a foot (0.3m) long, and then sent to a thermal power plant for combustion to generate electricity. However, the power plant charges them a combustion fee of $11 per ton. When gypsum board and cement block are sorted, they need to be crushed, and then sent to a road construction company, but Norcal needs to pay the road construction company by total tons submitted, and these extra processes are a cost to the company.²² In New York, America’s biggest city, C&D waste:

“...has become one of the largest budget costs for local governments. Landfills are reaching capacity, with thousands scheduled to close within the next few years. The construction of new

²⁰Text proper in Chinese: 娄鹏，施工过程中对建筑垃圾的控制探讨，《现代商贸工业》2009年第01期
²²Text proper in Chinese: 新华网洛杉矶 2005-6-17 电通讯：将建筑垃圾变废为宝——访旧金山诺考尔建筑垃圾处理厂
http://news.xinhuanet.com/world/2005-06/18/content_3101535.htm
facilities for either recycling or disposal is enormously contentious, fueling ongoing battles between waste exporting and waste importing states. This is a particular issue for New York City, which no longer has any disposal facilities and must export all the waste it does not recycle. The closure of Fresh Kills Landfill, New York City’s last remaining landfill, has resulted in a $400 million annual increase in the NYC Department of Sanitation’s budget since 1996, and the City's shift to waste export no doubt provided added impetus for the $4 per ton tax that Pennsylvania recently imposed on waste disposed of in its landfills.23

The US Environmental Protection Agency have stated that “reducing and recycling C&D materials conserves landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall building project expenses through avoided purchase/disposal costs.”24 However, this approach could mean use of flexible concepts of deconstruction as the environmental changes require more costly processes, making conventional building too expensive. Such a shift will have much to offer in the application of the principle of the 3Rs. Design research for deconstruction or disassembly is forming a new perspective which could broaden the scope of sustainable design and become the most advantageous complement and challenge to conventional architectural concepts. For much the same reason, the Canadian Standards Association developed a voluntary guideline regarding design for disassembly and adaptability in buildings in 2006.25 The document is meant to provide guidance and a basic set of principles for architects, engineers and building owners to consider.

1-2-2 Mega-event buildings have further worsened cities’ already overcrowded situations

Urbanisation has already caused problems. In the 18th–19th centuries, cholera, a disease associated with cities, “…reached near-epidemic proportions in the rapidly industrializing and urbanizing Western world, where it was the leading cause of death until the early 20th century.” By the 21st century urban disease refers to all the ills of the urban population that come through industry, transport, and excessive concentration of people in one place. Among all symptoms of urban diseases, the large urban population growth is the major source of other symptoms, such as the appearance of traffic congestion, resource shortages, urban poverty, and pollution.

Taking Shanghai, where the 2010 World Expo has just ended, as an example, the population in Shanghai reached 24.334 million in June 2012, a 45% increase compared to 2000. Further, the latest statistics show the population coming from China’s other parts has reached 9.823 million, a 183% increase compared to 2000. This has led party committee members to appeal for the means to upgrade the industrial structure, dredge and stop up the population combining with comprehensive management, and resolve the problems of urban disease facing by Shanghai. More and more local people think that Shanghai is getting crowded as it is more difficult to use transportation to go to essential services, like the doctor and school. In fact, the local resident population is ever expanding, especially over the past ten years. The resident population in Shanghai is about 23.47 million, while 11 million people live within the 600km² outer ring and the population density is up to 37,000 persons per square kilometre in the downtown area. New York is another expanding city. As the three time host city of major expos, the population of New York is expected to grow by 1 million to 9 million by 2030—and the infrastructure is already crumbling.

Urbanization is a process whereby a certain region’s population is concentrated in towns and cities, which also means city expansion and the diffusion process of urban culture, lifestyles and values in the rural hinterland. Urbanization is thus a gradual process of moving a traditional rural society dominated by agriculture to a service-based modern urban society, including transformation in population numbers, place of residence, industrial structure and land use. In order to solve the problems of living and employment, a large level of infrastructure must be set up. Such infrastructure includes the construction of high-density residential areas, continuous updating of roads, increasing the road network, and development of new industries and associated real estate. In a modern city, especially in China, it is hard to find a piece of land which is not full of tall buildings, houses, streets and roads. According to Chinese data in the next 20 years it is expected that 12 million rural people will move to urban areas every year. According to statistics, the vast majority of the world’s poor live in South and Southeast Asia, mainly in China and India, as well as sub-Saharan Africa and it is the poor who migrate to the cities in search of a better life.

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26 Shanghai journalist learned from the 11th session of the thirty-eight Chinese People's Political Consultative Conference (CPPCC) Standing Committee meeting in Shanghai, （http://news.online.sh.cn 2012-08-30 07:36 [来源]: 劳动报）

27 The Economist Newspaper (Apr 26th 2007), Greening the Big Apple - The mayor's long-term plans for saving the environment, from the print edition, www.economist.com/node/9090238
Because mega events normally celebrate the process of industrialization and urbanization, they can be associated with the pollution that goes with urbanization. Such pollution includes the increasingly prominent problem of soil pollution from heavy metals, which leads to serious environmental hazards, health problems related to the declining ecological environment, heavy and monotonous work making personal health conditions bad, and having a city full of unhealthy commercial entertainment activities. Consequently, the buildings at mega events need to show a new way of procuring and making buildings that will not damage the environment to the same extent.

1-2-3 Is it necessary to change the traditional design model?

The growing crisis in energy and the environment calls for innovative solutions in mega event buildings to control and reduce their impact on the host cities at point of design. Traditional architecture or current architectural design is a linear design process which is based on a series of long-term development frameworks. Its standard is grounded on the basis of function, aesthetics, basic health and safety, and economics. The new process of architectural design will need to consider change and development of future functions and meaning for the building and its environment. At present, only when problems show up is partial correction and transformation undertaken because long-term design is lacking. This could result in resources being wasted through not planning for change.

The generalized environmental functions of a building include its internal and external environment. However, each building also links to an architectural theory and is part of an unceasing evolution of architectural history. Therefore, architects should consciously account for sustainable development in building design and consider recycling as a starting point. Furthermore, if future development is taken into account from the beginning of design, not only in terms of space and time but also in choice of materials through construction recycling, this will make it possible to reduce greatly or avoid the adverse effects of various changes in conventional buildings, especially the wastes caused by abandoning a building prematurely. This approach will extend the building’s life-cycle.

In the process of building design, one solution cannot solve all problems. Architectural creation has never been a single idea, especially in various architecture sects and ideologies. Various design ideas exist and there are always different understandings of research into the methods of architectural design. Each city needs, as much as possible, mutual support of its construction functions, whether viewed
from economic or social angles. The aim is to have vibrant neighborhoods and communities full of diversity. Diversity is the nature of the city, and only with it can a city maintain a good ecological function.\(^{28}\) As a concrete feature of the expression of urbanization, mega-event buildings must similarly have diversity in form. So, “To consider the relationship between architecture and its environments with traditional design methods is far from adequate. We have to look at architecture from a massive and urban view. Architectural thoughts should shift from single buildings to building complexes, to urban and rural regional planning.”\(^{29}\)

1-3 Theoretical Frameworks

1-3-1 The principles of green building and evaluation standards

The essence of sustainable development is that, in the face of limited global resources and their restricted regeneration, human beings cannot destroy and abuse resources wantonly in the pursuit of future benefits. There is a need to handle the contradiction between long-term development and current benefits properly, based on full knowledge of the environment and its resources to eliminate the “deficit” in resource usage.

Sustainable building development is any building which takes sustainable development as its strategic goal. This will encompass the basic principles of construction practices as well as complying with appropriate architectural theory, creative design, science and technology and art and culture, as well as construction management regulations and operational system requirements. Green building is the result of sustainable development construction, the essence of which is ecological and healthy construction practices and outcomes. Green is the symbol of nature, being alive and vital, which means growth and development. Hence green construction is a kind of architectural practice based on the scientific principles of ecology that aims to create a building space environment where artifacts work with nature, through circling of resources and organic unity. Its basic principles and evaluating criteria can be briefly summarized as the following aspects.

- Construction and its built environment based on respect for nature and nature’s protecting principles should be coordinated and symbiotic with nature; minimize the negative impacts on the

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http://server.uia-architectes.org/texte/england/2zb1.htm
natural ecological balance caused by creating an artificial environment; and create an artificial environment that is organically combined with the natural environment.

- Following the principles of resource and energy saving and efficiency, all construction activities such as architectural planning and design, construction, operation, and management, should as far as possible conserve natural resources and reduce energy consumption; they should advocate economic, reasonable, practical and efficient usage while opposing waste and extravagance; they should adopt the methods that combine the artificial and natural, such as modern high-tech and traditional technology, in order to maximize the rate of use of the building resources and minimize energy use.

- Based on the construction principles of health, recycled sanitation, zero pollution and waste, the built environment should be beneficial to people's physical and mental health. Non-toxic, harmless, green, lasting, recyclable and renewable materials should be adopted to avoid or reduce environment pollution; additionally full use should be made of natural clean energy, such as solar, wind, geothermal, and hydro energy; water recycling systems and solid waste and rubbish collecting, retrieval and recycling and safe disposal systems should be set in place; it is important to develop three-dimensional green landscapes and make parks and other green space protect and improve the constructed and natural environments, to satisfy the psychological desire of modern people to return to the natural.

- Building space and use functions based on open and flexible principles should adapt to the social development and needs of people; building space should be inclusive, with comprehensive functions, flexibility and adaptability, as well as being easy to be developed further. This will make sure it has a lasting vitality that matches its material durability, which will not only satisfy its current requirements but also avoid a large level of frequent rebuilding when its function is lost. In this way building can have huge potential for saving energy, materials and money, as well as comprehensive benefits to reduce the production and pollution in the environment. Architectural planning and design should be viewed as a continuous dynamic growth process. People should have the foresight to research interactive relationships between construction and social development; and combine short-term with long-term planning to leave room for later expansion and renovation. The goal should be "elastic design", "reserve design" and "latent design", giving priority to the adoption of construction and structural methods, equipment and systems with inherent flexibility and variability. Through modularization and standardization the building should be easy to maintain and update in terms of construction equipment and parts.
Green construction based on the principle of ecological architecture should express the modern ecological culture and aesthetic consciousness with its unique architectural technology and art forms, to create a modern architectural environment which is natural, healthy, friendly, comfortable, vibrant, colorful and full of traditional and local culture.

The 3Rs of building can be summed up as the sustainable use of building materials, parts and elements, architectural space and the external environment, noting that these are four interlinked levels. The first two levels concern substances, and the latter two levels mainly deal with space.

Regarding the theory and practice of sustainable design, there have been many such theories and no less than ten are listed in a current Chinese text book.  

Vale, Brenda & Robert’s *Green Architecture: Design for a Sustainable Future* was the first of this kind by pointing out that green building is not only considering the single building on its site but also includes the sustainable development of the urban environment. The latter is also more than just buildings, as it can be looked at as a built environment formed by all kinds of interactive systems of life, work and leisure. The *Guiding Principles of Sustainable Design* lists detailed rules for sustainable architectural design. The following are the six rules related to sustainable building design:

- placing emphasis on understanding the place to be designed, and continuing the cultural context;
- enhancing public awareness of applicable technology, combined with the functional requirements, using simple appropriate technology;
- establishing awareness of the need to recycle construction materials, making maximum use of local renewable building materials, and avoiding using high energy, harmful, waste producing and radioactive materials;
- according to the local climatic conditions, make use of passive energy strategies and try to use renewable energy;
- improving the flexibility of building space in order to reduce building volume and use of resources;
- reducing the damage caused by the construction process on the environment and avoid wasting resources and materials.

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In this thesis, these are the principles that need to be applied to buildings for mega events.

1-3-2 Urban Renewal

Because most events projects incur substantial expenditures in creating facilities, the ultimate goal for almost every host city with mega events is to realize at least some urban renewal in the affected districts. In this way, urban renewal and mega events form a perfect match. Tracing back the history of city development, the whole process is a metabolic process that is constantly updated and changed. Because since the 1950s city development was seen as social engineering to help capitalist economies in some developed European countries this has led to world-wide urbanization. However problems have appeared along with the city, such as living environment deterioration, slum creation, house and a built environment constantly under repair, leading to cities losing their its unique features. In the post-industrial era, big changes have happened to world economic structure, which makes the original functions, layout, and infrastructure inadequate. City renewal is seen as essential, and today cities are renewing in emerging and developing countries with unexpected speed. In the case of Shenzhen in China, this modern city was a small fishing village when it was designated as a special economic zone in 1980, with a target population of 300 thousand people which has, however, now exceeded 10 million in 2010. Its attraction to immigrating people appeals far beyond what policymakers expected. Shenzhen also invested huge amount money and constructed the sports venues for the 26th Summer Universiade, which is the first major sporting event in the city. This linking of hosting a mega-event with city development also occurred in the developed world, especially with the decline of traditional economic activities in postindustrial cities such as Manchester. As a result, mega-events linked with urban renewal programs are becoming increasingly important. The hosting of large international events is not only beneficial for the tourism industry but it is linked to all aspects of economic and social development. Manchester has actively sought a program of tourism and cultural events as a means of showcasing the city as well as accelerating the process of urban renewal. The Manchester 2002 Commonwealth Games were linked with existing efforts to achieve long-term urban renewal. Using sporting activities as part of an urban renewal plan began in the 1970s in Indianapolis,
United States. This attracted the attention of many other cities when Indianapolis claimed that they used sporting events to rebuild a declining city. Aimed at stimulating economic recovery and promoting urban development, United Kingdom’s Sheffield, Birmingham, Glasgow and other cities invested a lot of money in sports facilities, while hosting and organizing major sports events.\textsuperscript{36}

This kind of city renewal does not include compensation for physical wear and tear, such as housing repair, alteration and reconstruction. In fact, the fast development of electronic digital technology has given urban renewal yet another rich and profound meaning. \textit{Urban Renewal: New City Course of Development}\textsuperscript{37} was published in 2011, suggesting that piecemeal renewal is not sufficient and that cities need to have a forward-looking and strategic starting point. This statement is open to discussion, if the view is taken that city development is a metabolic process. Each city has its own unique features and finding a renewal method that suits different national conditions should persist in the sustainable development and people-oriented approach, while considering both local short and long development processes. City reconstruction should follow the real needs of the citizens. Constant reconstruction is normal and its positive meaning is to prevent city decline and promote city development.

“Metabolism is one of the fundamental rules in the development of human settlement. Architecture is the discipline that deals with human settlement, so it should regard the physical objectives of construction as a system of circulation. The life cycle of buildings should be regarded as a fundamental factor of design.”\textsuperscript{38} Event buildings that are demountable and use KOP building systems can adapt to the changes with their inbred flexibility. Even if not longer serving high-end events, they can easily switch to other civic and infrastructure projects, so that their life cycle grows with urban renewal.

The modern city develops rapidly and its change processes are accelerating due to improved science and technology as well as culture. City decline is not only material aging but is also reflected in functional and structure decline, this is a kind of relative decline or invisible wear. Therefore, the cause of modern city renovation begins not with the physical deterioration but with intangible change.

\textsuperscript{36}Luo, Qiuju et al.\textit{(2011), An Empirical Study on the Economic Impact of the Events with Input-output Model: A Case Study of Canton Fair, China}, ACTA GEOGRAPHICA SINICA, Vol.66, No.4, Apr., 2011

\textsuperscript{37}Text proper in Chinese: 于今（2011），《城市更新：城市发展的新里程》北京：国家行政学院出版社

The speed of physical wear tends to lag behind the city’s growing needs, while the latter directly decides whether there is a need for the renovation of the old city.

1-3-3 Appropriate Technology (AT)
AT is a type of popular technology, which relies on the best modern knowledge and experience, but which is engaged in the distribution of support for lifestyles on the basis of ecological principles and which carefully uses rare resources. It makes knowledge, experience and resources effectively serve human beings, but not so they become the slave of machines or technology. In accordance with the theory, the development and popularization of a technology is related to the society's capacity for accepting the technology. In 1983, the OECD published the results of an extensive survey of appropriate technology organizations entitled, *The World of Appropriate Technology*, in which it defined appropriate technology as characterized by "low investment cost per work-place, low capital investment per unit of output, organizational simplicity, high adaptability to a particular social or cultural environment, sparing use of natural resources, low cost of final product or high potential for employment.”

Any technology choice lower or higher than the capacity may have a bad effect on the normal and reasonable development of the economy of a society. Therefore, AT is a technology which fits the special condition of a region, because it regards the region’s capacity for containing the technology as an important aspect of choosing the technology, making AT the best choice of technology under the limitation of local conditions. On one hand, AT is not universal, while on the other hand, it is not against the application of modern industrial technology. AT comes from three sources: firstly, from the improvement of traditional technology; secondly, from the transformation and adjustment of advanced technology; thirdly, from experiment and research which directly serve the establishment of AT. Therefore, AT cannot be described as advanced or backward, for it is a technology mode which satisfies each region. AT is also important to sustainable construction, for it recommends selecting the technology mode, and material types which comply with the local conditions (including economy, culture, biology) when designing the construction to obtain the best benefits.

1-3-4 The definition of adaptability
Generally, adaptability is concerned with the capacity to be adjusted to suit new situations. In the segmentation process of architectural literature, the current definition of adaptability is a synthesis of

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accessible, open plan, and performance-based buildings, namely ‘the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life’. In 2006 the Canadian Standards Association developed a voluntary guideline for design for disassembly and adaptability in buildings. The document is meant to provide guidance and a basic set of principles for architects, engineers and building owners to consider. The guidelines, to a certain degree, are the logical extension of the concept of Buckminster Fuller’s Dymaxion House and Cedric Price’s anticipatory architecture of beneficial change. To be adaptable a building must be demountable first. Due to the availability of a disassembled structure, brought about by industrialized prefabricated technology, the mega building has the potential to be made adaptable for functional change and adjustments in its life cycle. Demountable construction is necessary for a mega building to accommodate any future changes in the urban fabric. Such an approach also addresses the issue of urban sustainability and required flexibility. Architecture should offer an incentive to its users to influence it wherever possible, not merely to reinforce its identity but more especially to enhance and affirm the identity of its users. Adaptability is emerging as an important consideration in the design of buildings for lower environmental impact.

1-3-5 Substituting a linear usage pattern with a circular usage pattern

The linear usage pattern of the modern built environment generally tends to a process of: access to raw materials from the earth’s resources; processing; building constructing; and finally abandonment. The building system should be an integral part of ecological systems, thus avoiding outputs in the form of waste when the building finishes its service life. The linear model can consume a large quantity of non-renewable resources and lead to short circuiting of the biosphere and regional and global ecological processes. This consumption of resources consists of two types, direct and indirect consumption. Direct refers to the large amounts of materials that are used only once. Indirect includes two aspects; one is new products produced to replace the waste caused by abandoned ones; and the other one is energy consumed through the excavation, production, and transference of raw materials that affects the surrounding ecosystem. Most manufacturing processes do not consider the future

41 Canadian Standards Association, CSA (2006), Z782-06 - Guideline for Design for Disassembly and Adaptability in Buildings, Mississauga, Canada
43 Herman Hertzberger et al. (2001), Lessons for students in architecture, Rotterdam: 010 Publishers
changes and functional development of the product, including buildings. The lack of long-term design means that partial correction and transformation will only be performed when a problem arises. Although most manufacturing processes are clear in purpose and easy in operation, the emphasis is too much on immediate benefits, ignoring time, which results in wastage of resources.

The pattern of circular usage is based on a circular framework, which can be regarded as a changing cycle in which every single use process is a cycle. Low input, high utilization and low waste emission are three aspects that make a cyclical usage pattern blur the sharp conflict between environment and development. The aim should be to change the value of mass production, mass consumption and mass disposal in the modern industrial civilization and build a recycling-based economy and society characterized by best production, best consumption and least waste. The recycling of buildings avoids the wholesale demolition of old buildings and also retains cultural heritage. Macroscopically, all materials are a part of the biosphere and there should be continuous material recycling. Microscopically, the cycle of a building material should be a complete cycle from design – build – use - abandon- and then back to design.

When considering future development at the very beginning of design, it is not only necessary to consider the degree of space and time, but also to take building recycling into account to maximize, avoid, or reduce the negative effects of various changes, especially the cost involved in abandoning buildings too early. The first aim is to increase the building’s service life, and then design in ways in which the building can be recycled when this service life ends.

Recycling of architectural space and the external environment should also be part of a complete. Recycling does not mean simple repair, as in the theory proposed by American landscape architect Lawrence Halprin.\(^{44}\) Recycling differs from preservation or repair, which makes the existing structure inside and out remain fairly close its original look. Recycling changes a building’s functions, so that internal spaces are readjusted to be acceptable.

The essence of this kind of move in circles is the continuous cycle of building life, not only building preservation, demolition or rebuilding. When the economic life of construction ends its cycle, construction as an object has already finished its life cycle if using the method of demolishes and

rebuild. However, appropriately changing and refreshing the building and its external environment, gives it a new function, thus extending the original construction cycle. In a broad sense, this is a positive city development mode, which preserve historical information and still allows good development, with ecological, economic, cultural and social significance for the city.

1-3-6 Prefabrication is still effective for today’s buildings

When it comes to modern design, the Bauhaus made a significant contribution to modular standardized production. However German orientalist Lothar Ledderose put forward a generalized theory that modularization was not the product of modern Western history but had existed in China for five thousand years. Chinese craft and art production existed for thousands years within the modularization concept, but it is still not clear when China began to apply similar modularization techniques to modern architecture. The Chinese tradition of creation is one of personal freedom in assembling modules, an approach which could make the object meet the standards and reflect personality. This is a rule of creation rule in ancient China that cannot be broken in both arts and production. Modularization is bound to lead to division of labor and quality administration, making material production in China a highly systematic and continuous process.

When comes to modularization, standardization and mass production will also inevitably appear in people’s mind. Together these concepts seem far away from the definition of arts and architecture for many people, but creativity is not limited to “innovation” in a narrow sense and modularization does not always mean mechanization and standardization. A variety of goods can still be achieved. The variety of combinations and scale when taken as a whole with the details are the most two important means of avoiding uniformity. Taking the Terracotta Warriors for example, permutation and combination played a huge role and the combined processing and manual detailing of the modules helped to form the image of a group portrait of individuals clearly in the same army.

1-4 Scope of This Thesis

At the time of completing this thesis, an article published by Xi’an University of Architecture and Technology, stated that recently green building has become the focus of research in the discipline of

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45 Armstrong, P. J.(2008), From Bauhaus to m-[h]ouse: The Concept of the Ready-Made and the Kit-Built House, www.scholarworks.umass.edu/cgi/viewcontent.cgi?article=1007...wood

architecture and engineering among Chinese academics. The article applied methods of bibliometrics and statistics for a multi-dimensional study of 2781 research papers on green building which were published between 2007 and 2009 in China. The statistics of the research, based on the high-frequency of keywords and the interrelationships between these words, revealed that the most investigated research topics included Green building evaluation indices, standards and systems, LEED standard and Whole Life Appraisal/Whole Life Costing. However, there was no thought to the holistic procurement, maintenance and life of the building, which is the view of sustainable building taken in this thesis.

The sustainable building concept is an approach that should embrace the total scope of architecture, which is different from general architectural thinking where the building is conceived as an object, often without people, and which is only photographed the minute is it is finished. Rather than this emphasis on theory, image and style, the main thing underpinning sustainable building is to emphasize the design ideas and specific technology and link these with the life of the building, in order to minimize environmental impact over the whole building life. Therefore, this thesis put focus on the necessity and feasibility of recycling and design research, specifically related to the KOP approach, and specifically for super events under the guiding principles of sustainable urban development.

1-5 Research Methods

Historically, research regarding a building’s adaptability is sparse in most industrial countries. This phenomenon is probably related with an architectural tradition, as normally the significant building is designed as if for perpetuity. Adaptability comes in two main forms, the reuse of buildings through their modification as needs change and the more extreme idea that the building might not be a permanent fixture, but designed to be dismantled and re-used in a different location, and possibly in a different configuration. This is the investigation of adaptability that is examined in this research.

Reviewing current literature regarding demountable buildings, there is no finding which can fully answer the question about the sustainability of a system of reusable components, not to mention specific research related to the use of a kit-of-parts system for buildings for major events. Without a systematic theoretical grounding, this investigation has had to rely heavily on observation, and the empirical method.

“"The empirical method is generally characterized by the collection of a large amount of data before much speculation as to their significance, or without much idea of what to expect, and is to
be contrasted with more theoretical methods in which the collection of empirical data is guided largely by preliminary theoretical exploration of what to expect. The empirical method is necessary in entering hitherto completely unexplored fields, and becomes less purely empirical as the acquired mastery of the field increases. Successful use of an exclusively empirical method demands a higher degree of intuitive ability in the practitioner."\(^4^7\)

In fact many ideas and methods are incomplete or imperfectly shaped at first, but are evolved gradually, being developed and manifested through their ability to be adapted and perfected during the whole process. In trying to discover whether a kit-of-parts approach is appropriate for major events buildings, this thesis has undertaken data collection from the following methods with the intention of synthesizing the results.

- **Survey:**
  
  In order to understand what users and those involved in making events buildings think two surveys were undertaken, they are:
  
  1) A questionnaire survey mailed to a sample of users, and then collecting, sorting, and statistically assessing the results.
  
  2) One-on-one interviews with people directly involved in the events industry.

- **Archival Research:**
  
  Special attention was given to archival resources, as the only authoritative statements the objectivity of which can be ensured are acceptable as evidence. Because this research looks at existing buildings and systems it makes use of commercial web sites, but attempts to find multiple confirmation of information from such sources where appropriate.

- **Observational Method:**
  
  The purpose is to undertake observations of events buildings in use (and disuse) to obtain relevant information. The observations will be undertaken and reported in a systematic manner. Case study buildings observed will be assessed using a framework to test their level of sustainability.

- **Interdisciplinary research:**

The intention is to merge the results obtained from the research investigation identified above, which will mean techniques, methods and theories from multiple disciplines and perspectives to achieve the goal of answering the research question.

- **Comparative Analytical Method:**
  As part of the interdisciplinary approach there will be comparison of comparable data, as a way to reveal the differences and contradictions. Comparison is the most basic method of analysis, as without comparison the analysis cannot be started.

In particular, this research is deeply influenced by Method of Dual Evidence, which was initially used for combining document based materials with new material from archaeological field investigations. The method was advanced by a Chinese scholar, Wang, Guowei\(^{48}\) and is widely considered to be the major innovation of Chinese archeology and textual criticism in the 20th century. The value of the Method of Dual Evidence was later affirmed by important founders of modern Chinese architecture, Prof. Liang, Sicheng\(^{49}\) and Prof. Liu, Dunzhen\(^{50}\), who practiced this method in the field of architectural history.

This research is based on gathering information from a range of field investigations, which have involved travelling extensively between major host cities of urban events in four continents, among them the almost uninhabitable Tibetan Plateau.

\(^{48}\) Wang, Guowei (Chinese: 王国维; December 2, 1877 — June 2, 1927), was a Chinese scholar, writer and poet. A versatile and original scholar, he made important contributions to the studies of ancient history, epigraphy, philology, vernacular literature and literary theory.

\(^{49}\) Liang, Sicheng (Chinese: 梁思成; 1901–1972) was a creative architect who has also been a teacher of architectural history, a pioneer in historical research and exploration in Chinese architecture and planning.

\(^{50}\) Liu, Dunzhen (Chinese: 刘敦桢; 1897-1968) was a famous contemporary Chinese architect. Together with Mr. Liang, Sicheng they laid the foundation of using modern scientific methods of research in the ancient architectural heritage of China.
CHAPTER 2 URBANIZATION, EVENTS AND THEIR CONSEQUENCES

Following the once flourishing age in events history represented by Expo, Olympics and matching convention centre in some countries of Europe and America, the exhibition industry in the whole of Asia is booming. Recently, the appropriate authority in Taizhong (Taiwan) declared that International Convention and Exhibition Centre (TICEC) will open for its first exhibition in October 2011 after a long gestation period. As reported by Taiwan journalists before, the new TICEC will occupy 13,500 Pings\(^51\), which are Taiwanese level ground measures, and will have multiple functions such as exhibition space, convention facilities, shopping, entertainment, office, business, culture, housing, and a transport interchange. It has been estimated by the developers that the new TICEC will bring in earnings of 60 billion Taiwan Yuan yearly from the outcomes from commercial activities such as shows, sightseeing, housing, and food and drink sales. These commercial benefits will be estimated from the results of holding 52 large-scale exhibitions, 786 conferences and having 6.73 million visitors per year.\(^52\)

Taiwan is not the only example of an expo and convention centre promoting the growth of the local economy. The Hong Kong Convention and Exhibition Centre (HKCEC) opened in 1988 on reclaimed land. The second phase of the centre, located on an artificial island, was constructed from 1994 to 1997 with a bird-like roof profile as its distinctive feature. However, the original area was not enough for its activities and it was extended for the third time by the construction of an expanded exhibition hall connecting to Phase One and Phase Two (Fig.2-1). It is one of the most important expo and convention centres in the world with more than one thousand exhibitions and conferences each year.

What is the reason for such constructing on such a large-scale? This

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51 Taiwanese square measure, each unit is equal to 3.3057 square metres.
52 Chen, Pingcuo, China Times, Taiwan, May 7, 2008.
chapter is an attempt to establish the pattern which exists behind all observable phenomena.

2-1 Earnings in the short term are not everything

Being the most important industrial and commercial city of South China, Guangzhou is currently creating another miracle of economic change based on holding international exhibitions. Guangzhou was first involved in this in 1957. After more than 50 years of involvement in the development of both the local and the Chinese national economy, the China Guangzhou Import and Export Trade Fair (CGIETF) held twice a year is considered to be a window on China. In addition, more than 1,100 exhibitions and expos of all kinds are held in Guangzhou every year. Besides space rentals, total income comes from exhibition building, site renovation, advertising, logistics, restaurants, tourists, hotels, and transportation services. For example, the CGIETF is held in spring and autumn every year lasting almost two weeks on each occasion. During these times the hotels near the CGIETF area raise their charges by a factor of ten. Daily rent for a private residence becomes US$70-80 which is four to eight times the normal cost. Guangzhou exhibition practitioners have been heard to say “A city holding an exhibition is just like throwing out money from a plane in the sky over this city.”

Certainly new exhibition and convention facilities will bring benefits and some sense of cultural development to the local and international communities involved. Nevertheless, there is also the possibility of damage to local environments when the building of emulative new and large exhibition and convention facilities becomes a trend or even a means of competition between cities.

Some observers have predicted a high attrition rate in the exhibition industry due to over-building and the resulting glut of space. Half a dozen "first-tier" cities of the United States have expanded their facilities two or three times during the past 10-15 years. According to Marquardt’s research, multiple facilities exist in several of these cities, and in some instances original centres less than 20 years old are being abandoned for totally new and significantly larger facilities soon to be built. Convention centres in these cities can approach 1 million square feet of exhibition space and up to 3 million square feet of gross building area.

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53 Text proper in Chinese: 100.02.24 會展課程簡介. See: mail.tsu.edu.tw/~mike/what_is_mice1000223updated.swf, pp12.

Immoderate building trends in large exhibition and convention facilities are only one side of the issue. The architectural design of mega buildings is very different from the design of ordinary commercial buildings. It usually involves use of state-of-the-art technology. These building typically contain main spaces such as auditoria, competition and display halls, which are all long span structures that make use of all kinds of superior quality and strength materials (Fig.2-2). Because of this high specification they have high costs for their running and maintenance as well. They also often occupy vast acreages of arable land, and this has an environmental and ecological impact, and even where the land was reclaimed from the sea this impact cannot be ignored.

In the history of mega buildings, these exhibition complexes only emerged in modern cities about thirty years ago. However, for another type of mega building—the sports complex—many other examples can be found. The magnificent Athens Olympic stadium is now a white elephant. It costs Greek tax payers as much as US$102 million dollars each year just to maintain in its unused state. For economic reasons, the main stadium of the Atlanta Olympics has been demolished. Sydney’s stadium has been partially demolished and the government pays AU$46 million each year for the maintenance of the remaining structure. Another example is the finished China Tenth National Games (Sep.13 to Sep.28, 2005) in Nanjing. In total twenty-seven stadiums and gymnasiums had been set up or rebuilt for the Games with a total floor area of 700,000 square metres. Lump sums of 5000 million RMB were spent on all facilities as a single construction investment. However, the Nanjing Olympic Sport Centre, the main stadium of the total 27, requires that more than 60 million RMB be spent on its maintenance every year. More importantly the Centre occupies 89.6 hectares of land. Although construction expenses can be partly retrieved through multiple business developments, the land cost plus the maintenance expenses every year will make this huge stadium responsible for a substantial deficit. Furthermore, the effective life of these mega buildings is quite short; they may be out-of-date after 15-20 years and sometimes after an even shorter life.

The site for World Expo 2010 Shanghai is estimated to occupy about 8.53 square kilometres. Such an extensive land use will incur huge after-use maintenance fees, and land use as a variable cost will also be a large figure. Smart solutions should be created to avoid this problem. Throughout China, vast construction projects are planned and in process. The energy consumption of building activities accounts for 27.6% of general national energy use, and the energy for production of construction
materials takes up 13% of the whole nation’s output of energy.\textsuperscript{55} What is more, both figures are growing rapidly. Large scale construction activities have used up large portions of natural resources including land, all of which are not recyclable, reusable or reversible. Obviously, these resources and numbers are more important than any momentary earnings because they are related to the living environment of people. Compared with a longer and more permanent impact on the environment, the earnings in the short term are not everything. What are some of the compelling factors that have brought about these phenomena?

2-2 Urbanization Trends

In the last hundred years, urbanization has been one of the most important social and economic phenomena. Since the 1960s, the whole world has experienced the process of both urban-renewal and re-urbanization, and the globalization of development has also appeared. Especially from the 1980s onwards, there has been a profound revolution in the new international division of labour and economic globalization, led by international companies. In turn this has produced a large translation in the production model, social system, and economic structure of global society. In order to become accustomed to changes and adjustments in industrial organization and social systems, countries in both the east and west are focusing on the transitions in the economic and social systems, which are bringing everyone around the world into the global economy. This has resulted in a net of urban systems, remodeling the global city system. The result has been the appearance of global cities, global city-regions, metropolitan areas, and the megalopolis\textsuperscript{56} as a clustered network of cities with a population of 10 million or more.\textsuperscript{57} This means globally urban systems and regional landscapes are facing destabilization and reorganization. According to the continuum theory of society and space, social production and space production are interactive, so social vicissitudes certainly influence the vicissitudes of urban space structure.


\textsuperscript{56}Megalopolis was used by Lewis Mumford in his 1938 book, The Culture of Cities, which described it as the first stage in urban overdevelopment and social decline. Later, it was used by Jean Gottmann in 1957, to describe the huge metropolitan area along the eastern seaboard of the U.S. extending from Boston, Massachusetts through New York City, Philadelphia, Pennsylvania, Baltimore, Maryland and ending in Washington, D.C.

In the last half century, telecommunications with their satellites and networks have undergone great development, such as the rapid popularization of personal computers, international networks, and individual communication systems. These have changed people's lives in varying degrees and have caused a tremendous change in all aspects of social life, especially to the way people communicate and transmit information. Applications of digital technology are widespread, covering graphic technology, scientific calculation and database technology, virtual reality technology, satellite image analysis and 3S technology, ATM (Asynchronous Transfer Mode) technology, network technology, system interoperability, metadata, and many other high technology areas. Digital technology is having an enormous influence on the way people understand the environment and human existence and social ideology and economics. It is bringing people into a new era- the digital age stamped by the characteristics of dematerialization, demobilization, mass customization, intelligent operation and soft transformation.

The technical developments of the present time have led people to become filled with curiosity regarding all new things, and it is feared this will injure tradition. When McLuhan said that “the city no longer exists except as a cultural ghost for tourists….the city is obsolete” it was easy to disagree but now this situation is closer to becoming a reality. Because living in the past is impossible, people have already walked along the future path and the world's technological development is far from what was previously imagined. As the prophet of the new information age, McLuhan's foresights about the impact of new media are being actualized at unprecedented speed via the Internet. McLuhan portrayed technologies as an extension of man, illustrating how human senses are massaged and perceptions altered as these devices become an integral part of cities. The old-style city is being submerged by the digital tide, and the Internet is changing the city's infrastructure enormously. This brand-new infrastructure will have new community relationships and may create a new kind of human city or may stay within the built form that already exists. According to Marc Angélil, “The traditional City has come to an end” thus questioning the survival of the traditional urban fabric. Continuing from

58 PCS (Personal Communication Systems) will provide the convenience of FAX, Email and voice mail in a package similar to cellular phones. See Wireless and Personal Communications Systems by Vijay K. Garg et al.
59 For further information on these issues, see H. Inose and J. R. Pierce, Information Technology and Civilization (New York: W. H. Freeman, 1984).
where his best-selling *City of Bits*\(^{62}\) left off, Mitchell argues, in his subsequent book *e-topia "Urban Life, Jim—But Not As We Know It"*\(^{63}\) for an extension of the definitions of architecture and urban design to encompass virtual places as well as physical ones. He answered the above questions by suggesting that it is time to redefine urban planning and development as well as re-examine the role of architecture.

*As the emphasis shifts away from the design of enclosed objects, the design and manipulation of larger surfaces will move to the forefront. This paradigm shift necessitates that the relationships between the urban elements be redefined. Future reuse is of utmost importance. Instead of proposing elements serving only one function, the disciplines of landscape, architecture, urban planning, and engineering are asked to develop dynamic spaces with a multiplicity of functions that can be changed according to society’s needs.*\(^{64}\)

### 2-3 High-rise Buildings and Urbanism

As population numbers grow and the competition for land increases modern cities have embraced high rise buildings, producing a new urban form in which the human scale has been superseded by the large. The modern city implies high rise building.

#### 2-3-1 The skyscraper and urbanism

It is not only that urban attributes are owned by high-rise buildings, but also that the urban attributes of high-rise building are much stronger than for other building types. The following discussion will help to explain why urbanism is so strongly related with high-rise building.

Firstly, architectural urban attributes refer to the ability and character of built form and the way these affect exterior urban public space.\(^{65}\) Different buildings cause varying degrees of impact on urban public space; consequently, the urbanism ‘owned’ by them also has different strengths. When a building or group of buildings can produce more effect on urban public space at the large space scale, and the people who can feel the effect are numerous in number, of varied types, and with different

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\(^{64}\) Udo Greinacher, *City is Dead - Long Live the City: Developing Future Models of the City*. Speech of Where Do You Stand, 99th ACSA Annual Meeting, March, 2011

\(^{65}\) 赫尔穆特·博特等，*今天的城市性(Urbanity Today)* 《国际城市规划》2010年第4期
activity scopes, then this building or group of buildings can be considered as having strong urbanism. Conversely, when a building or group of buildings produces less effect on urban public space in small scale spaces, and the people who can feel the effect are fewer in number, of a single type, and with narrow activity scopes, then this building or group of buildings can be considered as weak urbanism. The strength or weakness of a building’s urban attributes depends not only on the characteristics it has, but also on both the environment of the city and its surroundings. Because skyscrapers are large and dominant buildings and part of the urban environment of many people, they fit the first definition of having strong urbanism.

2-3-2 Problems raised by the boom in high-rise buildings

Many high-rise buildings of all types are already globally accepted as the sign of a metropolis and these play an integral part in city life. However, rather than discussing all of their advantages for modern cities at length, it is possible to focus on a few of the issues caused by having large numbers of tall buildings in a city environment. Shanghai and Hong Kong have been chosen to illustrate the phenomenon.

Statistics showed that in 2009, Shanghai already had more than 400 ultra-high-rise buildings, ranking it as the world No.1 in these terms. However, there is a serious issue in the layout of high-rise buildings in Shanghai regarding the city image. Contradictions, like too high a density, a reduction in green land and insufficient sunshine, are serious in the areas where high-rise buildings are concentrated. More generally, such buildings are distributed at random without order and lacking environmental design, meaning they cannot form a cityscape. In some examples, high-rise buildings are freely set in heritage areas, which have caused damage to historic features. For example, the forests of tall buildings around the Shanghai Exhibition Centre form a serious threat to the protection of historic buildings and historic districts where many heritage buildings are located. An example is the Moller Villa (Fig.2-3) which has been identified as an outstanding example of modern architecture and a key national heritage building for conservation by both the European Society of Architects


67 Text proper in Chinese: 郭嵘,焦守丽,吴阅辛; 哈尔滨市域城市化发展对策研究. 中国城市规划学会 2002 年年会论文集 2002 年

68 Text proper in Chinese: 张高峰等, 上海陆家嘴金融中心区超高层建筑外部形态设计影响因素分析, Zhang, Gaofenget al. Factors Affecting Outer Configuration Design of Super-high-rise Building in Lujiazui Financial Centre of Shanghai City, Central China Architecture, 02/ 2009 第 27 巻
Design Authority and the municipal government of Shanghai, for its elegant and unique style, and mysterious and rich history. Even residential courtyards in this area, the so-called “New style of Shikumen,” have heritage value. In these, Western decoration with a foreign flavor is attached to the traditional style of folk houses originally from south of the Yangtze River. Most houses were built during the 1930s and are rich in the vernacular architecture of Shanghai. In another area full of high-rise buildings, Lujiazui along the Huangpu River in Pudong, buildings are fighting for the best floor area to height ratio, and are developing rapidly towards the Huangpu River (Fig.2-5). Moreover, some high-rise buildings of the riverside are racing to turn their facades toward the Bund, a famous tourist area in Shanghai of historic buildings and wharves along the riverside. It seems that the view of streetscape and waterfront along the Huangpu River is more important than preserving a famous tourist destination. Buildings like these seem to be people-oriented and user-centered, but the overall benefit to the city and a relationship to urban space have been cast aside.

Besides this, Shanghai is facing a serious problem of land subsidence in the urban ecological environment, due to the large numbers of high-rise buildings which were set up in a comparatively similar time, coupled with over-exploitation of groundwater and underground works. According to officials of the Research Center of Land Subsidence of China, Geological Investigation Bureau in Shanghai, Shanghai is subsiding at a rate of 1.5cm per year,\(^69\) with the biggest single annual subsidence being 10cm. Lujiazui, a tiny area, subsided by an average 3cm in 2002, due to a large

number of high-rise buildings being created in its vicinity, especially the land around the Jin Mao Tower which sank by 6.3cm. Subsidence in Shanghai has long been an issue that residents worry about. In addition, the summer temperature in the areas with high-rise buildings is higher than that in surrounding areas with a lower built environment, because of the forming of a “heat island effect.” Of course, Shanghai is not the only city affected by this problem. Almost all “vertical” cities are unable to avoid it.

As one of the most densely populated places in the world, Hong Kong is a typical high-density city (Fig.2-4) and its land population density reached 6,480 persons per square kilometre in mid-2009. Kwun Tong, with 53,110 persons per square kilometre, was the most densely populated among the District Council districts. However, 67.4% of Hong Kong’s land area is woodland, shrub and grass. Country parks and special ecological areas designated by the government as protection zones make up over 38% of Hong Kong’s land area, while residential land only accounts for 6.1%. The large number of urban open spaces, high land utilization, control of residential development density, and an improved public transport system are the basic experiences of urban construction in Hong Kong. In the past few decades, Hong Kong has proved to the world that high-density does not entail overcrowding and poor living conditions; instead, it has showed how to create a workable, efficient and vibrant city in a high-density living environment. However, Hong Kong’s urban development is not perfect, and dense high-rise buildings have brought some negative effects.

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Looking at these problems, firstly the screen effect caused by too many high-rise buildings has made a great impact on the urban environment, and this shows most prominently in the city construction of Hong Kong. This screen effect, whereby an almost solid wall of high rise building is created, spread across the city suddenly from the late 1990s. This phenomenon has caused an outcry from green groups and residents nearby who complained that it prevented fresh air flow, and heated the whole block, which affected air circulation and sunshine for the old neighborhoods which mainly consisted of 6 ~12 storey building. In addition, when the Kong Hong government ruled that it was not necessary to account for certain items in the approved structure area, the quality of buildings further deteriorated, especially in the podium part which could increase in size.\textsuperscript{73} In order to promote green building design, in 2001 the government further removed certain building area parts associated with improved environmental effects from the overall calculation of density to encourage their inclusion in projects. These included hanging gardens, balconies, broadened public corridors and prefabricated exterior walls. These parts tend to expand the building body by 20% to 30%. These expanded high-rise buildings seemed, on the surface, to be a sign of the prosperity of Hong Kong, but the result is that environmental quality in the city has gradually been sacrificed. The Hong Kong Observatory has claimed that the reduction of wind speed will lower visibility in the high-density city, heighten urban temperature, and prevent pollution dispersal.\textsuperscript{74}

It is necessary here to further discuss the screen effect which is called the wall effect in HK. There has been increasing concern since 2006 over the "wall effect" caused by uniform high-rise developments which adversely impact on air circulation. Due to the density of Hong Kong's population and the economies of scale of mass developments, new private tower block developments tend to be made up of 10 to sometimes over 100 towers, ranging from 30-to-70-storeys high. Developers of housing estates are financially motivated to maximize the view, at the expense of the free-flow of air. Huge wall-like estates along the waterfront are often constructed.\textsuperscript{75} In fact, this phenomenon is seen in most high density cities in mainland China. Fig.2-6 clearly shows that there are nearly 30 commercial and residential towers with heights of 100 to 130-metres along a 10 km stretch of the river bank on East


\textsuperscript{74}Ibid.

Riverside Road in Guangzhou. Shanghai has a better solution to this problem. The Shanghai Urban Planning Control Technology's Stipulation, passed in 2003, has predetermined that where the building height surpasses 60 metres, the greatest length of continual development cannot surpass 60 metres. It also stipulates that for buildings up to and including eight stories in height the continual developed length cannot surpass 80 metres.  

Secondly, from the viewpoint of urban landscape, after 1997 the development type of private and mixed-function is Hong Kong's main model for urban development for renewal and reconstruction. Without doubt, this type helps the city to run in a more effective way. Usually residences and office buildings 40~60 floors high are based on 15~20 metre retail storeys and transportation hubs. Construction base levels are usually built close to the ground boundaries in order to obtain the biggest development potential, while towers and private recreational facilities are carefully isolated to ensure privacy. Elsewhere in recent years, some commercial landmarks in Hong Kong like Langham Place, Festival Walk, APM Shopping Mall and other large commercial development projects have been interlinked with subway stations, to solve properly the link between building and city and to reduce isolation. These are also considered by Hong Kong as business models and are being copied by many mainland cities in China. However, these large development methods are having a further impact on the Hong Kong landscape as the building block is becoming bigger and bigger due to the merging of adjacent land and unified development by a single property owner. In recently developed areas, the proportions of the old streets are gone. Huge blocks have redefined social spaces, which has turned people away from public streets to an indoor and private environment, taking street stalls and local commercial street activities away. There will no longer be colorful street life in the new districts. In conclusion, new and old street areas will form two extreme disproportionate polarizations.

### 2-3-3 Usable spaces among high-rise buildings

After examining the issues created by the development of high-rise buildings above, there is a forgotten place as yet untouched by most architects, which is the land formed by the sunlight access requirements of some urban planning authorities, such as those of China. Sunlight issues in urban planning administrations however, are not necessarily the main problem in determining the distance between neighbouring buildings in the planning process, because the electrical power supply acts as a

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substitute for natural light in most developed countries. However, the solar south (in the northern hemisphere) is still the most popular direction for daylight, especially for residential buildings in less developed countries like China where urban construction land is under intense pressure leading to the boom in massive high-rise buildings. This causes problems, as if a high-rise building is arranged on the south side of a land parcel this often causes problems for the land parcel on the north side. Any development here has to be at the extreme back edge of the site to guarantee the building on it will achieve the necessary access and meet the sunlight ordinance. This problem has already affected the orderly development of urban land, and there is still no appropriate solution for it in Chinese regional planning management bodies.\(^{77}\)

With the increase in city-oriented development, more land has been set aside for local municipal construction projects, especially for high-rise buildings. As a result, there are more spaces among high-rise buildings for sunshine access being created in these high-density developments and these small land parcels have a very high potential for being used for temporary events. If these kinds of spaces were sometimes covered by demountable, adaptable buildings the value of such precious urban land would be realized at its optimum level. Moreover, this approach would mean that valuable land around the city would not be covered with permanent structures to house temporary events, and would thus be available for residential development with this mixed use approach. Since, in cities like Shanghai, both exhibition developments and residential developments are linked to extensions of existing public transport networks, a single transport development could be designed to serve both uses in the mixed use approach.

### 2-4 The Problem of Land - Taking China as an Example

Land is the material basis of human survival and the one most precious and limited natural resource. It is common knowledge that China has the largest national population in the world. The contradiction between population on the one hand and socioeconomic development, resource utilization and environmental protection on the other is acute, whereas the state's need for all of these is growing year by year. Since the 1990s China has begun to experience accelerated urbanization. Compiled by the China Association of Mayors, the 2007 China Urban Development Report was released in Beijing on

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the 31st March 2008. The report showed that China's urbanization process would continue to maintain a high growth momentum. By the end of 2007, the nation altogether had an urban population of 594,000,000 and an urbanization rate of 44.9%. The Chinese economic historian Dadao Lu enunciated clearly that China's urbanization rate increased from 17.9% in 1978 to 39.1% in 2002, and this level set a world record. The UK spent 120 years achieving a similar rate from 20% to 40%, the United States spent 80 years, Japan 30 years, and China only took 22 years. However, Dadao Lu pointed out that the rate of 43% comes with a lot of false promises; it is essentially an urbanization of land and a rash advance. He put forward the argument that Chinese urbanization development, planning and construction is pursuing large-scale development blindly and this is leading to a serious waste of land. The direct consequence of these tendencies nationwide is the building of a series of international metropolises, with ultra-luxury office buildings, main roads, great plazas, green spaces and university cities. The serious consequence is that large areas of high-quality cultivated land are occupied and the arable land area is reduced substantially.

Under the process of massive urbanization, the development of many of China's cities has gone beyond the normal level, and from this urban construction have emerged disorders with some development out of control. This process has caused more and more contradictions and conflicts between social and economic issues, resources, ecology and environment, and has already constituted harm to the country’s development of a sustainable social economy.

An inevitable phenomenon during the time of urbanized advancement is urban sprawl. It is noteworthy that there is an entirely different characteristic between China and a developed country's urbanized advancement, namely that Chinese city sprawl is created together with the urbanization and is carried on at the same time. The causes of urban sprawl in China are mainly the rapid growth in

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78 Lu, Dadao (陆大道, 1940-) has engaged in research into economic geography, and land and regional development particularly in the assessments of the evaluation factors of industrial layouts. He initially established the theoretical system of the industrial geography of China, contributing a large amount of empirical and theoretical research in China's regional development, regional disparities and regional sustainable development, and was elected a member of the Chinese Academy of Sciences in 2003.


urban population, the demand of residents to improve their living conditions, disorderly construction of eco-technological development zones, migration of college campuses from urban districts to the suburbs and the construction of ring expressways in major cities, which promote the suburban spread. For example, there are already six such rings in Beijing, and as an industrial city in northeast China the city of Shenyang also has three. Additionally, more urban residents with higher living standards are also demanding land for recreation, leading to things like golf course construction. Golf is one kind of outdoor activity rooted in nature. It is not like soccer, tennis and other sports which can be played at designated venues in any outdoor places, including those between the high rise buildings of the metropolis. A golf course itself should appear to be natural, even if totally man made, and for this reasons golf courses often occupy desirable land. For example, golf clubs in Beijing are generally located in scenic areas near water.

With the rapid development of China's market economy, to meet the social needs of high-class life, many cities have had to build all kinds of leisure and sports facilities, of which the construction of golf courses is the most prevalent. Generally, because of the need to be connected with a “natural” environment, the location of a golf course is selected to be some way away from urban development, and mostly in the suburbs. Another reason for such selection is quite simply the pressure for land in the city to be used for building. However, if a course is too far from the city, the worry is that it will not be convenient for the club members because of the travel distances. Recent golf course construction in China has already been recognized as one of reasons for urban sprawl. Such a conclusion is based on two significant features of the golf courses recently constructed in China.

First, there are many golf courses presently under construction in cities, although there is a great dispute about the number of golf courses in the Beijing area. The latest report from the Chinese Ministry of Land and Resources, which recently used satellite remote sensing images to inspect the enforcement of land usages, confirmed that the nationwide phenomenon of the illegal construction of golf courses is serious. There have been more than 170 occurrences including practice fields in the peripheral areas of Beijing alone, which has shown a tendency to surround the capital with golf courses. Among these, at least 70 illegally occupy arable land. Second, the area of many golf

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82 Ibid.
courses is too large. Whether as ordered by a high-level policy-maker in the golf club or the government’s chief executive manager, most golf courses meet international standards. "For an 18 holes golf course at least 48 - 50 ha of land should be available,"83 but concurrently with the setting up of some luxury golf villas and other facilities, an international championship standard course will occupy at least 100 hectares of land in China. Apart from the relatively small areas used for driving ranges, usually golf is criticized because a large area of arable land is occupied for the leisure of a relatively small number of people.84 Taking the area for building an 18-hole golf course as 100 hectares, a total area of 38 standard courses built in Beijing is equivalent to 5,322 standard soccer fields.85 In fact, all of these golf course developments have been driven by huge financial benefits, because the price of a golf villa is higher than a similar villa in the peripheral land sector by more than 30%.86

This example suggests there is a need to see land in cities as a non-renewable resource that has to be developed with considerable care, and not just left to the open market. In fact, land needs to be treated as a multi-functional asset, just as some buildings are. This suggests the need for more use of temporary and reusable buildings in cities.

### 2-5 Dynamic and Changeable Cities

Essentially the city is the place where people come to earn money rather than ‘growing’ it in a subsistence setting. This economic basis of cities is both their reason for being but also the root of modern urban problems. Divorcing people from where food is produced and wastes recycled has broken the natural cyclical order of most lifestyles. This means that the link between cause and effect has been broken. This, in turn, is why many cities vie to hold a mega event even when the financial problems of doing this have been well documented. What is needed is a city that recognises it needs to exist within resource limits. This will lead to cities that are dynamic and changing rather than being permanent monuments, as in the past.

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84 See also Time to Eat the Dog?: The Real Guide to Sustainable Living by R and B Vale, Publisher: Thames & Hudson (15 Jun 2009).
85 The FIFA standard football pitch size is 68 metres × 105 metres, a total area of 7140 square metres.
86 Text proper in Chinese: 海南 70%高尔夫球场亏损国家级贫困县疯狂建设 (Xu, Zhijiao ed. Total 70% loss of Hainan golf courses with crazy construction of it in some state-level poverty counties, Shihua Financial News, 2010/04/01, http://content.caixin.com/NE/01/ub/NE01ub11-all.html)
2-5-1 Urban industry

With the further development of information technology and the internet economy, the way the global economy is growing involves fundamental changes. Now knowledge production, dissemination and application are being seen as a source of economic growth, and new knowledge-based economic forms are emerging. The local tendencies of knowledge production and consumption activities have led to some emergence of “new industrial space” and the formation of new regional economic patterns. The emergence of new industrial space is the spatial effect of urban competition within the background of globalization. International trade, investment and the global expansion of multinational companies have become a major force in the emergence and development of new industrial space, and together the worldwide adjustment and upgrading of industrial structures have forced many cities to be restructured and reorganized. This new industrial space and the international economic incentives to compete and integrate with each other have together been an important space node in the process of globalization. Therefore, economic globalization and the new economy have created a competitive environment and background to the division of urban space. In this background one of the spatial effects is the emergence of new industrial space often causing the total restructuring of urban functions and reconstruction of city space. With the deepening of globalization, urban space has also entered a transition period where structure scale, form and function are under strategic reorganization or reconstruction. Traditional urban space faces vast changes, due to the influences of the momentum of the new industrial developments, consumer demand, a diversified investment system, and the concept of sustainable development. Meanwhile, with the process of urban industrial structure adjustment, function reorganization and accelerating expansion, there are emerging new large urban industrial spaces, using the new technologies. These include a changing central business district which has to adapt to the presence of new business districts, and these are having a big influence on the original urban spatial structure.

Under the influence of digital technology, people's behaviour is no longer limited to study, work, communication, and leisure happening in different physical places, but extends to the network, computers and other digital technology to build a virtual community. Time and space are altered in a new approach to work and leisure. The people of Hong Kong can continue the unfinished work of the British during the day, and the CEO of a multinational company in North America can take a close look at current projects around the world without leaving the office.
Digital technology has permeated all areas of the city; the traditional city’s functions are undergoing a profound transformation. Digital technology relieves the spatial constraint on human behaviour, blurring the space boundary of human activities. Working at home has produced the ability for business people to work in a flexible manner and the places of work are now scattered and diversified.  

At the same time as more and more people are owning cars, with the consequent pressure to build more and more roads to contain these, shopping as well as trade is no longer restricted by space and distance. The emergence and the development of electronic commerce, distance learning and cyber-culture have reshaped the form and strength of interaction between people as well as between city and region, and have thus caused the reclassification of inhabited space. For example, businesses can move out from the centre to cheaper suburban locations as there is no longer the need for the physical proximity that comes from being in the CBD.

Because of the possible reduction in land price caused by the change of business locations and the application of the information network, the intensity of use of land in the central urban area could be reduced and the crowded conditions will be improved as a result. In the centre it is possible that the cultural entertainment function will be enhanced and businesses will be scattered. In the traditional city the central area usually contains the business, administrative, financial and leisure functions with a high-intensity of land use. However, in the digitized age of e-commerce and virtual banking the central urban position of the CBD is challenged. Recently there has been a tendency for the CBD to be substituted for with a multifunctional CA (central area) in European and American cities, “…downtown is one part of central area and financial district (i.e. CBD) is one part of downtown.”

Digital commerce and intelligent management will also enhance the comprehensive utilization rate of city space and transportation efficiency in the future. The land thus saved can provide space for the improvement of the urban environment, either through mixed use development with more residential development in the centre or by having more parks and green space for leisure activities. At the same time, the core urban design concept of the digital age should be to manifest the value and significance

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of human beings, and to express respect for human beings and nature. Therefore, the proportion of public open space, such as green land, parks, and squares could be increased in the spatial structure of the future city. It is important to take measures that are adapted to local conditions so as to retain the city’s natural ecological territory. Compulsory legislation should be set to protect urban ecologically sensitive areas, as well as restoring and reforming ecological functions, through actions such as river pollution control and remediation, spillway dredging, and urban forest planting. The city’s spatial structure should display its ecology and its user-friendly characteristics.

Digital networks also break the limitations on space and distance. Transportation is no longer the most important problem in the development of economics and society. However, digital communication cannot be a total substitute for interpersonal trust, mutual sharing and close communication, all of which are necessary in the process of creating progress. No matter where it is, the central content of the new economy is still closely connected with workplace. “Cities have always been regarded as the fulcrum of human communication, the place of possibilities and opportunity, either economic or political.”

Cities must still be designed as places for people to meet other people.

### 2-5-2 Migration in China

Data in this section has mainly been based on the Chinese book of *The Evolution of Economic Space in China's Major Cities* together with some other Chinese published writings.

The 1990s was an unprecedented migration period in China. Total national rural to urban migration rose to 124,662,500 people during the 1995-2000 period, increasing 3.65 times compared with the total migration of 34,127,600 people in the fourth census 10 years previously. There are four population convergence regions experiencing large-scale net immigration in the country: the Pearl River Delta region, Yangtze River Delta, Bohai Rim, and western Krai. The Pearl River delta region is the biggest population convergence region in the nation, and Guangdong province is the “super province” having the largest net immigration of 10,829,000 people in 5 years, giving an average annual net immigration of 2,166,000 people. This is equal to creating two Guangdong mega cities with a million people every year. Meanwhile, Hunan Province was the top place with net immigration of 2,430,000 people in 5 years; followed by Sichuan province with 1,695,000 people; the third one

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was Guangxi autonomous region with 158,000 people; and then Jiangxi and Hubei provinces both with over one million.

The Yangtze River Delta, of which Shanghai is the centre, is also a powerful population convergence region with 1,979,000 net immigrations into Shanghai, 1,763,000 people into Zhejiang Province, and 741,000 people into Jiangsu Province in 5 years, in a total population of 4,483,000 for the three places together. This was quite a big migration in terms of the Yangtze River Delta which is already a high population density area. Bohai Rim, with Beijing considered as the centre, is an important population convergence region in north China, with 1,670,000 net immigrations into Beijing, 393,000 into Tianjing, 391,000 into Liaoning, and 28,000 into Shangdong. Although 94,000 people moved out of Hebei Province, the total net migration was 2,424,000, and the annual average net migration was 484,000, somewhat less than in the previous two examples. The western edge of Xinjiang, Tibet, and Yunnan Provinces were also quite attractive convergence zones, and the net immigration was 1,350,100 people. Xinjiang especially had 950,100 people move in, just followed by Beijing in fourth place overall.

Although rural to urban migration has some positive social and societal impacts, because of the system of social exclusion in employment, everyday life, and social communication, most migrant workers cannot settle in cities, and thus are left in limbo as “semi-urbanized.” It follows that the issue of migrant workers poses a core challenge for China’s urbanization. In the view of urban planning and design it brings some extra and higher requirements for both quantity and form, such as sufficient housing, infrastructure, and services to absorb the inflow of migrants. This means that city planning has to be flexible enough to cope with change in a short time frame.

2-5-3 The uncertainty and unpredictability of urban development

1) Conventional urban planning and sustainable urban development

Land use planning should be based on co-existence and co-prosperity (live and let live) with the surrounding environment, and there should be a corresponding means of appraisal of the steps being taken towards the goal of co-existence. At the same time, planning should not only deal with sunlight, wind and other physical environmental aspects between a site and its surrounding environment, but also with landscape integrity as well as context continuity. For example, when planning transportation, full consideration should be given to the current situation and future development, trying to be highly efficient, reasonable, convenient, and with a means of controlling things that damage the environment,
such as the number of cars on the roads. When formulating transportation planning, the environmental and economic elements should be taken into comprehensive evaluation, including evaluation of impact on the city, the natural environment, and the urban ecological environment, along with energy-saving and pollution reducing aspects. In the meantime, efforts should be geared to developing an information industry dominated by the internet as a means of reducing daily travel, improving work efficiency, managing distribution infrastructure to minimize transportation, and constantly promoting urban function.

To achieve this urban planning must be carried out on the basis of abundant investigation, developing not just an overall plan for the layout of transportation for instance, but integrating water supply and drainage, power supply, telecommunication, fuel supply, thermal energy, the natural environment and reforestation, with earthquake resistance and disaster prevention in this as well, thus enabling the city to function well at many levels. As part of this there is a need to look again at green open spaces within the urban environment. Urban green space system planning needs to be reformulated to establish an integrated, multi-level, stereo metric urban afforestation system, including urban public green land, green areas in residential quarters, green spaces belonging to private organizations, green areas for environmental protection, landscape greening and road greening, and effectively improving the green coverage rate in the city and the per-capita public green space through the creation of green networks.\(^{91}\)

Although rational comprehensive urban planning has dominated planning practice for almost a century, it is probably no longer able to resolve today’s urban development dilemmas in modern rapidly urbanizing cities, especially in Third World countries.\(^{92}\) Because of its functions, comprehensive urban planning “had to embody a vision of the long-range future.”\(^{93}\) As a result of the emphasis on the plan’s rationality and its comprehensive nature, the whole process from the plan investigation, research, establishment, disclosure to the public, until the plan authorization is long and time-consuming. In England and Scotland, the average time for the comprehensive planning process

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usually takes about four to five years. The complexity and time-consuming nature of planning means contact is lost to some degree with local communities, which means the plan can never really reflect their needs and this can lead to change in their nature in a relatively short time. In addition large-scale planning has developed into a bureaucratic system. The prime tasks of this system are project examination and approval, thus the loss of flexibility makes planning often unable to cope with a rapidly changing market. As a result, the crucial outcome of comprehensive urban planning is its relatively slow response to the kinds of problems that often arise from the uncertainty or unpredictability of rapid urbanization.

2) Why change is inevitable and necessary for urban development

Urban planning is a very comprehensive social science. For making a proper urban plan, subjects such as history, nature, economy, society as well as the status and trends of all kinds of industries and fields should be taken into full consideration so as to scientifically predict and properly arrange for future urban development. Before many major programs of great significance are unveiled, the opinions of specialists and the public are also solicited and the approval of higher authorities is required. Thus, the question arises that since the plan has gone through cautious analysis and reasoning, since it is ensured of being scientific, rational, prospective and authoritative, why does it need constant adjustments and modifications? The reason, in fact, mainly lies in the following three aspects.

First, urban planning, in conformity with the changing urban conditions, is a process of dynamic and sustained historical development. Specifically, as it is based on a present period featuring rapid development and great changes, it is imperative for it to be capable of prompt adjustment and implementation. This characteristic is not only determined by the theory of urban planning, but also regulated by law. For example, according to the current regulations of China, the duration of the general plan for urban development is normally 20 years with a major adjustment required every 10 years. Furthermore, in China, according to the urban development strategy and the government service deployment, the essential targets of urban planning are divided into short-term objectives, medium-term objectives and long-term objectives. Taking a 5 year plan as an example, the short-term goal refers to the goal which must be achieved within 1 year, the medium-term objectives refer to

goals which must be achieved within 2-3 years and long-range objectives refer to goals which must be achieved within 3-5 years.\(^95\)

However, due to the excessive growth of cities, some general urban planning has proved to be out of place only a few years after its establishment, as the population and the scale of the city have reached the goal set for its long term future. Taking Nanjing as an example, the first round of its general urban planning was ratified by the State Council in 1983, and in 1990 an adjustment to it was ratified again by the State Council while 2000 witnessed another timely rectification in line with the prevailing conditions of Nanjing.\(^96\) Recently, the Nanjing Municipal Standing Committee deliberated and adopted the "2007-2020 Master Plan Outline."\(^97\) With more than three years for its development, the top five domestic planning institutions participated in the work, which involved more than 430 professionals over 2 years.\(^98\) Now there is a need to consider how to plan Nanjing in the future looking 10 years and even longer ahead. All these processes are necessary and conform to the legal requirements.

Secondly, urban construction and development has in itself some unpredictability and urban planning is not always correct, since no matter how rational it is, it is merely a prediction looking towards the future. Cities, intertwined in an enormous and complicated system, have various elements to balance, many variables to consider and many unpredictable situations that could emerge which are out of the scope of the planning department. The sudden outbreak of SARS in 2003, for instance, meant planning departments had to take action the moment it occurred. This led to rapid rearrangements of the plan which were made as quickly as possible. In the case of Nanjing, this meant assigning the Nanshan Hospital as the center of prevention of the further spread of SARS. Another example concerns the problem of parking. This has arisen because of the country’s relatively recent shifts in policy to promote the development of the automobile industry, which has meant that cars are rapidly


making their way into households in China. This situation was beyond imagination 10 years ago, and now since it is happening, it calls for adjustment and improvement in the planning of parking areas. Thirdly, urban planning is carried out at a macro level to guide the city’s future development. This makes it impossible to provide explicitly for all exhaustive situations, no matter whether these are big or small. Moreover, because town planning involves various professions and domains, complex situations and many variables, flexibility and uncertainty are inevitable. An example of this is the Nanjing Metro Line 1 which was planned to determine its basic location and direction as early as 1986. However, it needed not only further investigation and design, but also certain adjustments and changes to specifications because the buildings on the ground and the underground pipelines had frequently changed location. Taking this case further, to deal with the rapid urban development in the province of Jiangsu, currently there are a total of 17 metro lines being finished or in construction in its capital city of Nanjing. Even Metro Line 1 has had a South Extension of total length 25.08km opened on May 28, 2010, and the planned North Extension has just had its preliminary study finished.

Urban planning is a prerequisite for the construction of buildings and green space and for the spatial conditions which will be needed to give people a decent life. When unforeseen circumstances have prevailed leading to the need for change, this will often cause buildings to be short lived and this is a waste of natural resources. To deal with the changing circumstances of uncertainty or unpredictability, designers have to consider adopting demountable forms for the built environment. In turn these will then have to be deployed on plots of land within the urban fabric that can have flexible uses.

2-6 Mega Events and Urbanization

2-6-1 The power of urban-branding

A geographical location or a certain sphere of activity can become a brand just like other marketable products. The power of urban-branding is to make a certain location known to people and bring about a natural association between urban existence and some image or suggestion. This power can spread its spirit to every building within the city, and let competition and growth co-exist within the urban realm. Urban-branding has irreplaceable economic and cultural embodiments and specific functions which cannot be traded.

99 For the Nanjing Metro Line 1, preliminary planning began in 1986 and trial operation of passenger running began on August 12, 2005.
Putting together the quintessence of a city’s natural and human resources, urban-branding in a highly condensed form, is often the primary motivator for high levels of urbanization. As an example Paris, as a fashion capital, is the result of centuries of accumulation of cultural and economic activity, from the Louvre to the Champs Elysees Avenue, which have become a symbol of its leading the world in fashion. The city of Los Angeles, known as the International Movie Capital, has not only developed the movie industry as its main branding economic activity but has also stepped into the expanding businesses of the movie industry, such as acting, sets, and special effects, as well as leisure tourism and the audiovisual industry. This is the unique effect of urban-branding and Expos have a place in this phenomenon.

2-6-2 Mega events and urban-branding

As suggested above, mega events have become a tool for promoting urban-branding and also a new strategic tool for urban development. Every mega event presents the uniqueness of the host city to the whole world and attracts the world to understand or even participate in the city’s activities. Thus such events can visibly or invisibly improve the popularity and influence of the city and then push forward development and urban economic construction. Examples of such mega events from the past would include the Seattle Exposition, Tokyo Olympic Games, Los Angeles Olympic Games, Osaka Exposition and the Japan-Korea World Cup.

The hosting of a mega event has become an important process in promoting the urban-brand. However, it will only be truly successful when integrated into the city’s urban strategic development planning. To host a World Expo, the Olympic Games, or even the Asian Games means having sufficient buildings and infrastructure that will in itself change the city almost completely to meet the needs of tourists from home and abroad for transportation, entertainment and daily living. At the same time this new construction can upgrade the urban development and improve the popularity of the city. In most cases the original intentions and aims of the city decision-makers or operators are usually focused on the latter purpose while the former one—the event itself, which has the deepest influence on the urban texture and function—is often neglected, so that the city is forced to accept the influence the event has left on the development of the urban sphere. This “for the event’s sake” construction can hardly be expected to bring any positive influence on the urban development, just as happened with the abortive Paris Exposition of 1989, as explained below.
2-6-3 Expo '89 and Paris

As one of the themes of Expo '89 Path to Freedom, the Project for the Third Millennium was based on a model of identical cubic pavilions, and was going to be held on two sites in Paris along the Seine. The first was in the west, now the site of the Parc Citroën Cevennes, and the second was where the Bibliothèque nationale de France (BnF) now exists. The problem was how to connect the sites together. One suggestion was that both sites were to be connected by pavilions that “hugged the perimeter of the site to leave a large public area in the middle where crowds could gather to celebrate the future; the pavilions were placed close together, “hand in hand” as one of the architects explained.”

Since the two bases were far apart and there was a lack of transport links, and an absence of guidance from an overall urban development strategy, the selection of the sites for the Expo led to many disputes. In addition, the architects participating in the associated competition were at a loss with how to proceed. Eventually, all three participants (Rem Koolhaas, Jean Nouvel and Ricardo Bofill) had to choose one of the two bases suggested. Finally, because of a lack of a unified consideration of the urban fabric, only separate studies were made for the fair and these were very different from each other. The relationships between Expo Design and urban development were obscure. Eventually, after making preparations that continued for two years, an announcement was made to give up the project. Had there been a realisation that holding the Expo meant first considering the future development of the city, this fiasco would not have happened.

2-6-4 Urban squares and public space

Normally, there is a considerable connection between urban public space and mega events. The globally networked economy is highly dynamic and selective. It tends to link up and connect together in a network what is valuable, and disconnects from the network what is not valuable. The structure of an urban square for a cultural event is commonly open in form. The important factor in organizing such a square is to integrate its surrounding buildings with the environment of the square, especially in terms of preserving any historic buildings, as these are a part of public space which has a cultural meaning. The space types and levels of a public square can be considered as a space structure based on the environmental system of the square. Abundant space levels and types are complements to the

100 OMA, Concept / Master plan for the 1989 World's Fair, Paris, www oma eu/index php?option=com_projects...
101 Gencel & Velibeyoglu, Reconsidering the Planning and Design of Urban Public Spaces in the Information Age: Opportunities & Challenge, Public Spaces in the Information Age, 42nd ISoCaRP Congress 2006
structure of the system, and help to ensure the square can cope with a diversity of demands. To enrich space structure and levels, techniques such as scale, degree of enclosure, and ground texture can be used to divide the square into principal and subordinate, and public and relatively private spatial domains. In this way it is possible to provide useful public spaces that can be linked with the holding of temporary events.

2-7 Machine Aesthetics and Hi-tech

2-7-1 Design ideology rooted in the industrial society

The United Kingdom has always been in the tradition of rational and logical positivism, which is expressed in an emphasis on modern structures, technologies and materials in architecture. This tendency towards embracing high technology in a rational manner has been viewed by the Architectural Association School of London as their particular tradition. In the late 1950s, the Architectural Association School was noted for developing purely technical and rational projects at the large-scale. People treated structure, circulation and the structural system as living objects in these projects.

As part of the development of this viewpoint, people began to adopt a biological form of expression. This biomechanical tendency introduced technology from other disciplines into urban and architectural design. Based on the living container or cabinet concept, a totally new city proposal was developed. In this the city was imaged as a movable container or cabinet. This kind of metal cabinet could travel around the world and float on the sea. These cabinets could therefore replace the city by connecting to any convenient suitable support and logistics system in the world. In 1968, Ralph Wilcoxon defined a mega structure as any structural framework into which rooms, houses, or other small buildings can later be installed, uninstalled, and replaced, and which is capable of "unlimited" extension. Many architects have designed such mega structures. Some of the more notable of these architects and architectural groups include the Metabolist Movement, Archigram, Cedric Price, Frei Otto, Constant Nieuwenhuys, Yona Friedman, and Buckminster Fuller. All, however, worked with the idea that such a framework would allow the structure to adapt to the individual wishes of its residents, even as those wishes changed with time.  


A design concept is the beginning and direction of design thinking. Machine aesthetics, as an ideology, played a critical role when design shifted from an artisan age based on a self-sufficient natural economy to an industrial society that featured mass production. Before the industrial revolution productivity was low, thus the aesthetic concepts which were presented by the dialectical unity of an economic base and superstructure were embodied in the perfect combination of technology and art. In turn this created the prosperity of traditional arts and handcrafts. The substantial increase in productivity and dramatic improvements in production processes brought by the industrial revolution separated design, which was to be full of innovative ideas, from the processes of manufacture.

This separation became a key step in the development of modern design, but also disrupted all kinds of previously established balances for artistic designing, resulting in the emergence and development of modern design. On the other hand, at an early stage, mass-produced products, often imitations of the hand-made predecessor, inevitably lacked the perfect manual skills required by superior design. A large number of machine produced inferior design products raised people’s suspicion about them (or “caused people to be wary of them”). Thus there emerged a stream of well-designed hand made goods alongside products from the factory. The latter were sometimes well designed and sometimes not. These two streams were both seen as part of modern design. This was also the process of looking for a new balance between the economic and the beautiful. One way this was achieved was by stripping decoration from products, making them plain and simple and easy to manufacture. In this way the modernist aesthetic was established. A product was to look fit for its purpose. What is intriguing is that many hand made products followed the same aesthetic (Fig.2-7).

2-7-2 The dynamic city and machine-like building
The middle of the 20th century and especially the 1960s was a period with an endless stream of architectural ideas and utopian programs. Architects and designers of this period believed that the advances in materials technologies and gradual improvement in the level of mechanization could release labour and provide more leisure time for people.
Through ideas about industrial prefabrication and large-scale production combined with new science and technology fantasies, the Plug-in-City, Walking City and the Nakagin Capsule Tower emerged in the UK and Japan during this period. Archigram, a group of architects which mainly consisted of Peter Cook, Ron Herron and Dennis Crompton, used popular art combined with imagined ideas about science and technology and combined them in an architectural language. This was used for urban design, and to try to find the solution to ideal city living by searching from a perspective of boarder factors, which included society, culture, art, and communication technology. In the 1960s they raised the ideas of life in the modern city which became manifested in a series of urban designs and exhibitions, such as the "Living City" exhibition of 1963.

The crisis which confronted mankind after the war in city construction had demonstrated that the existing principle of architecture, the theory of rationalism, and functionalism supported by modernism, could deal with the new urban problems. In order to form new a cultural language and themes based on criticism of the present, like those of popular artists, current designers of all specialities needed to face the reality, absorb inspiration and strength from the general culture and the logic of production and consumption, and rebuild the value system of architecture and urban space. As part of this movement, Archigram suggested creating a huge skeleton structure as the basic means to supply water and power, and adding to this the units of residences, shopping malls and offices. They thought that if they could solve the functional issues of architecture in this way, emphasis could be put on the buildings themselves rather than making the equipment and structure look artistic. They viewed the city as a residential machine, consisting of machine-like buildings which, like insects with their legs, could move around in a city and settle down when they found their proper places. From their point of view, architecture was not like a traditional academic exercise resulting in an immovable construction but something which could be overturned, bizarre and even fun. Their works basically only exist on the drawing board. They placed emphasis on the sense of logic, streamlining, machine equipment, technique and structure, and the effect of an exo-skeleton structure which exposed the structural and services components.

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Fig 2-8, analysis of Nakagin Capsule Tower, source: http://will.harbison.com.au/

Committed to the study and design of future urban structures as a reaction to rigid form, Japanese Metabolism created innovation through thoughts which advocated new technology combined with popular culture to produce a new spatial structure through the transformation of the traditional city. The Nakagin Capsule Tower (Fig.2-8) is a manifesto for the dichotomy between eternal and temporary. Metabolism thought that the city and its buildings are not static, but part of a dynamic system, like the biological process of metabolism. Kisho Kurokawa's building, however, was constructed as a permanent structure and was composed of two interconnected concrete towers, of respectively eleven and thirteen floors, which housed 140 prefabricated modules or capsules, each of which were self-contained units.\(^\text{105}\) Being produced by a manufacturer of transportation containers, each capsule unit measured 2.3 m × 3.8 m × 2.1 m and could be used as a small living or office space. Capsules could be connected and combined to create larger spaces. Each capsule was connected to one of the two main shafts by just four high-tension bolts and was designed to be replaceable almost instantly. “The capsules are all-welded lightweight steel-truss boxes clad in galvanized, rib-reinforced steel panels. After processing, the panels were coated with rust-preventative paint and finished with a coat of Kenitex glossy spray.”\(^\text{106}\) Design inspiration came from the spaceships of the former Soviet Union when Kurokawa visited there. The combination of the cabin body units with the frame structure could also be considered to have a precursor in traditional Japanese timber construction.

These representative works expressed some bold thoughts about the urban environment and took the need for increased urban flexibility to the limit. They also demonstrated astonishing imagination and foresight. Especially today when humanity is faced with a crisis of over-urbanization, such designs continue to have practical significance. Their avant-garde architectural style and thoughts about dynamism plus efficiency have since affected many architects and their work. More recently, the high tech Pompidou Centre of 1971 by Richard Rogers and Renzo Piano has partly realized their dreams of constructing the mega structure within which the functions sit, or at least it looks as if they do.\(^\text{107}\) Its interior includes an exhibition hall, library, all kinds of art, music, and drama activity rooms, laboratories, and stores. The function is complex, but the entire exterior is completely protected by a

glass curtain wall. In order to maintain the indoor spatial integrity, the steel structure and all kinds of equipment are all exposed on the exterior of the construction. In addition the open-air transparent plastic-covered escalator rises from the bottom to the top with twists and turns, and in doing so gives the building the appearance of a chemical plant. The indoor partition walls do not reach the ceilings; this means the partitions can be easily changed as functional needs change. The floor steel frame is also not camouflaged in order to present a uniform style both inside and outside. The Pompidou centre has achieved some kind of technological expressionism, sending out a unique aesthetic sense, among the old dusty bricks and stones in the Paris town centre. It has become the model of early machinery aesthetics and of high-tech construction.

Actually, the tendency towards high-tech appeared very early in buildings such as the Crystal Palace in London in 1851, and the Eiffel tower and the Machine Hall in the Expo of 1889. They were the ‘avantgarde’ buildings which displayed the new technology in the construction of that time, although in the early half of the 20th century this trend gradually disappeared. In the 1960s this ideological trend was active again, and re-publicized the machine aesthetic. As a result all kinds of steel frames, concrete beams and columns, and glass screens became separated elements expressed in structure and façade, as well as colourful pipes and ducts which were exposed outside without adornment. The aim was nothing more than expressing the fact that the new materials, structures, equipment and technology were superior to the traditional, and that new architectural design should consider the determinant factors of technology. This is followed by a new era of aesthetic factors where new technologies are used as decorative themes. Finally, function can be variable while structure is constant. A building could exist for more than a century, but the usable function will inevitably be developed during the long years of its life, so more attention should be paid to a reasonable technology for making flexible space which can meet the multi-functional needs as well as achieving the effects of a machine aesthetic.

2-7-3 Machine aesthetics

The ideological trend of high-tech architecture merged the architect, structural engineer, and equipment engineer into one organic whole. Designers who were part of this movement opened up the frontiers of architectural art in history. For example, an early exponent, P. L. Nervi, designed a variety

108 Text proper in Chinese: 建筑史话第一章建筑起源世界史第一节原始社会——混沌的空间

of fabricated reinforced concrete shells\textsuperscript{109} in the 1950s. Another early example is the 16 millimetre thick steel mesh shell (hyperbolic paraboloid) of the University of Mexico’s Cosmic Rays Laboratory\textsuperscript{110} designed in 1952 by F. Candela. He also designed the 40 millimetre thick polypetalous groined vaults of Los Manantiales Restaurant, Xochimilco in 1957. Both of these buildings are novel forms.

The geodesic dome was created by R. Buckminster Fuller to make a metal roof over a large span without intermediate supports. The US Pavilion designed by him in the 1967 International Exposition in Montreal, Canada demonstrated a wonderful outcome of this approach by using the structural system to make a spherical grid structure. During the day its acrylic skin sparkled in the sunlight, and when darkness fell, its interior lighting gave it a varicoloured glow.\textsuperscript{111} Also innovative was the West German Pavilion in that fair designed by German architect F. Otto, with the appearance of a tent-like structure with the spreading of a spider’s web. The experimental aerated structures of recent years are also examples of innovative buildings, most of which are demountable as they cease to exist as an envelope once the air flow is stopped. These new structures, with their new forms, are part of the technical aesthetic which the high-tech approach makes manifest.

In the United States there was also change. “Between two great wars – the Civil War and the First World War – the United States of America came of age. In a period of less than 50 years it was transformed from a rural republic to an urban nation. The frontier vanished. Great factories and steel mills, transcontinental railroad lines, flourishing cities, and vast agricultural holdings marked the land.”\textsuperscript{112} This industrialization was seen to be the making of America,

\begin{quote}
...many Americans before the Civil War had believed that industrial technology and the factory system would serve as historic instruments of republican values, diffusing civic virtue and enlightenment along with material wealth. Factories, railroads, and telegraph wires seemed the very engines of a democratic future. Ritual celebrations of machinery and fervently optimistic
\end{quote}
prophecies of abundance continued throughout the Gilded Age, notably at the two great international expositions, in Philadelphia in 1876, and in Chicago in 1893.\textsuperscript{113}

Both expositions together with Expo 1904 at St. Louis and the 1915 San Francisco exhibitions came after the United States easily defeated Spain in 1898.\textsuperscript{114} During this period the United States grew to become the world's leading industrial nation. The availability of land and labour, the diversity of climate, the ample presence of railroads as well as navigable rivers, and the abundance of natural resources all fostered the cheap extraction of energy, fast transport, and the availability of capital that powered this Second Industrial Revolution.\textsuperscript{115} This revolution pushed an expansion in organization, coordination, and the scale of industry, spurred on by technology and transportation advancements. The US soon became the country of strategic importance in Modern Architecture and led the trend towards high-tech design. Sigfried Giedion's book *Mechanization Takes Command* not only offered insights for that era into the intersection between mechanization and the imagination, but traced the various ways in which, for better or worse, mechanization assumed control of the lives of many ordinary people.

Buildings affected by this ideological trend are numerous. One example is the Convention Centre in Denver built in the 1970s whose roof slab is a complicated space frame. The size of it is about 206 metres by 72 metres, while the plot is approximately 14,832 square metres.\textsuperscript{116} The building's appearance takes full advantage of the structural aesthetic, as well as reflecting the impact of the trends at that time.

Mechanization and aesthetics have no connection in traditional thinking. Aesthetics is a subject allied to human appreciation of beauty and the discussion of beauty and beautiful objects, and is generally considered to be the philosophy of the art of beauty.\textsuperscript{117} Historically, there were no so called aesthetics in Ancient Greece, because the Greeks considered that the good was beauty.\textsuperscript{118} Aesthetics as a

\textsuperscript{114}Spanish-American War (Spain-United States), “The United States easily defeated Spain in the Spanish-American War of 1898. The war forced Spain to give up control of Cuba, the last of its colonies in ...” www.britannica.com/EBchecked/topic/...War/.../External-Web-sites
\textsuperscript{116}In 2005, a $300 million extension to the Center was completed, which nearly doubled it in size, and it now offers over 600,000 square feet of exhibit space, which can be subdivided into six separate spaces.
\textsuperscript{118}McGuckin, J.A. *The Notion of The Beautiful in Ancient Greek Thought and its Christian Patristic Transfiguration* - http://www.spc.rs/eng/notion_beautiful_ancient_greek_thought_and_its_christian_patristic_transfiguration_ja_mcgucki
discipline was first brought into being by Alexander Baumgarten as late as 1735. But this is not to say that people before that time did not pay attention to aesthetics, exploring and pursuing beauty as and when they could. The Industrial Revolution could be seen as a symbol of humanity stepping into the Age of Reason. The old gods receded and at the same time, a new god was created (humans are always creating gods), which was machine. Time controlled by the machine inevitably led to the new era dominated by the idol of energy. The machine aesthetic is the dramatic and logical result of this ground breaking transformation. Only now when energy supplies are coming into question in the face of increasing global demands for them has the occasion arisen to reconsider what an appropriate aesthetic might be for the modern built environment.

2-8 Brief Summary of This Chapter
The present springing-up and development of the global digital network is not just a communication system for the transmission of electronic mail, the World Wide Web, or a means of having digital television, but is potentially a brand-new urban infrastructure. This infrastructure could change the urban appearance enormously, in the way that the advent of railroads, highways, power grids and telephone networks did before. All these were brought to humanity by technology. It was not the first time that technology had expedited social change for humanity. If the steam engine emancipated humanity's hands and the automobile emancipated humanity's feet, rapid technological development in the area of digital networks is producing positive effects towards achieving sustainable urban development.

Today information technology is ubiquitous. All kinds of information products and services are permeating every aspect of daily lives, and quietly but also profoundly changing the city, its surroundings, living space, and the relationship between people. It is also a time to realize that the city is a dynamic instead of a static entity. Thus, pursuing the adaptability of buildings and land becomes a logical response to the challenges facing the urban environment. These ideas are pursued further in the next chapter of this thesis.

CHAPTER 3  THE OLYMPICS AS A MAJOR URBAN EVENT

In March 2008, a reporter from the New York Times had an exclusive interview with the Pritzker Prize winner of that year, Jean Nouvel. The latter suggested that buildings, like human beings, grow and change over time and may even one day disappear. “Architecture is always a temporary modification of the space, of the city, of the landscape,” he said, with the more philosophical comment, “We think that it’s permanent. But we never know.” With time and distance all buildings will disappear. Jean Nouvel illustrated his talk to the public with his design for the Red Sun Pavilion, a temporary pavilion for the Serpentine Gallery in London that opened on July 12, 2010. The pavilion is a scarlet cubist fantasy or “red movable tent” (Fig. 3-1, lower left). It is made from bold geometric forms (Fig. 3-1, lower right), large retractable awnings and a sloped freestanding wall that stands 12m above the lawn. Striking glass, polycarbonate and fabric structures create a flexible system of interior and exterior spaces. Almost at the end of his 30 minutes talk, a key final question regarding the structure’s mobility and recyclability was asked by a woman which caught the attention of the audience and gave the talk a meaningful end.

Fig. 3-1, two view of the Red Sun Pavilion

Nouvel’s Pavilion is part of the Serpentine Gallery’s annual series of Pavilions. In turn this is the world’s first and most ambitious architectural programme of its kind that annually gives prominent architects, usually the winners of the Pritzker Prize, a chance to show their approach to architecture in the UK for the first time. This programme thus brings the best of contemporary architecture to London for everyone to enjoy. There is no budget for the Serpentine Gallery Pavilion commission, but the

120Pogrebin, R., French Architect Wins Pritzker Prize, the New York Times, Published: March 31, 2008
The fact Nouvel’s Pavilion is in part supported by the ‘Sustain Programme’ suggests that a link is being made between demountable structures and sustainable buildings. This is a first step in dealing with the paradox of how to handle these high-priced structures (only lasting a few months in the summer) beyond such short-lived urban occurrences as the events for which they are designed. Are they an end in themselves or a beginning towards a more sustainable process of building procurement? This will be important to the public who live in London when they have to face a similar group of Olympic legacy buildings after the 2012 games.

3-1 Painful Lessons of Some Mega Events

At the closing of the 16th Asian Games in Guangzhou on November 27, 2010, the host city announced important news. Guangzhou’s Deputies of the National People's Congress and an academician of the Chinese Academy of Engineering, Mr. Zhong, Nanshan\textsuperscript{122} stated that both the direct and indirect investments\textsuperscript{123} related to the Guangzhou Asian Games were very big. “The total investment of 257.7 billion Yuan, of which investment of more than 195 billion Yuan was from Municipal Guangzhou brings more than 210 billion Yuan in debt.”\textsuperscript{124} Guangzhou is one of the five big national key cities, dominating the economic boom in the regions of the Pearl River Delta. As the host, Guangzhou has held respectively both the sixth National Games in 1987 and the ninth National Games in 2001. As a result it has constructed a large amount of infrastructure and a number of sports facilities, such as the Metro Line No.1, the Tianhe Sports Centre, the Guangdong Olympic Sports Centre, and the

\textsuperscript{121}Serpentine Gallery (2010), Press Pack - Serpentine Gallery Pavilion 2010 Designed By Jean Nouvel

\textsuperscript{122}Zhong, Nanshan was born in October 1936 in Nanjing, Jiangsu Province. He is now a professor and doctorate tutor, and an academician of the Chinese Academy of Engineering.

\textsuperscript{123}According to the Chinese Government's policy on mega events, the total investment in the Asian Games was estimated in two parts: both direct investment and indirect investment. Direct investment includes construction of sports venues and facilities, while indirect investment mainly refers to urban infrastructure construction and investment in environmental protection.

Guangzhou New gymnasium. If the economy of Guangzhou was overstrained at the completion of the recent Asian Games, this suggests that mega events can have a strong impact on a city.

3-1-1 Beijing Olympic Games
Beijing is another example of this problem. Two years after Beijing’s Olympic Games, the people who live in Beijing can see the consequences of the event on the city. Both the National Stadium (nicknamed the Bird’s Nest) and the National Aquatic Centre (nicknamed the Water Cube) remain open as well as the venues of the China Agricultural University Gymnasium, Peking University Gymnasium, Beijing Science and Technology University Gymnasium and Beijing University of Technology Gymnasium. The latter four venues are situated in four of Beijing’s universities and are being used rather reluctantly. Among them Beijing University of Technology Gymnasium was designed for the badminton and rhythmic gymnastics events of the Olympic Games with a total land surface 22,269 sq m and seating capacity of 6,900. Now it mainly serves student mass organizations. The Gymnasium offers great benefits to the students by only charging them symbolic fees. Some venues with less popular sports are facing very low levels of use even to the point of not being used at all. With rust stained outside fencing and trash everywhere, facilities such as the Xiangshan shooting range, Laoshan Mountain Bike Course, Shunyi Olympic Rowing-Canoeing Park, Beijing Olympic Green Hockey Stadium, Beijing Wukesong Sports Centre Baseball Field, and Fengtai Sports Centre Softball Field have nobody visiting to use them, and no organizations have rented them for a long time. Until now the city of Beijing has been not able to solve the problems regarding the usage of left over structures built for the Olympic Games, or other mega sport events such as the World Cup.

3-1-2 What the people think of the Beijing Olympic Games
Approaching the second anniversary of the event, a Yahoo China web page devoted to the topic of “Focus Attention: a Retrospective of the Beijing Olympics legacy” was set up. One of surveys in the article addressed the problem of idle facilities asking readers for opinions on how to solve the problem of idle Olympic venues. The voter turnout was 1,518 anonymous readers of this web page since Aug. 8, 2010. The multiple choice question and results of this vote are as follows:

1) There is no alternative for the lack of use, 10% (157 votes).

126 Text proper in Chinese, 难以解决的场馆闲置问题,
2) Even overseas countries have not resolved problem, so the Chinese cannot, 9% (139 votes).
3) Demolish to build tall buildings that can make money, 35% (533 votes).
4) Reducing the price of admission to all venues, 45% (689 votes).

The main body of internet users in China is below 30 years of age. This group of net-surfers accounts for 68.6% or just over two thirds of the total internet users in China.\(^{127}\) This means that the answers to this question reflect the young people’s expectations for the successful operation of these idle facilities after the games.

Regarding another question about their views on the huge investment made in the Beijing Olympic Games the voter turnout was 3,226 anonymous readers of this web page since Aug. 8, 2010. The multiple choice question and results are as follows:

1) Investment should have happened; China's formidable national strength needs to be demonstrated vigorously, 15% (479 votes).
2) It is pitiful, as what does such a huge investment gain finally, 56% (1,802 votes).
3) Actually, this is a pretty small investment! 5% (162 votes).
4) It is not necessary to speak out; all I have to do is keep it in mind, 24% (783 votes).

Although people do not know exactly where the money goes, they are obviously concerned about whether such a huge investment is worth making.

### 3-1-3 The problem of idle facilities in Athens

This lack of use of facilities was also the situation in Greece after the Olympic Games in Athens as mentioned earlier in this thesis. “A staggering 21 out of 22 venues lie abandoned since an event lasting just three weeks was held, and the magnificent stadiums are now over-run with rubbish and weeds. But the most striking 'legacy' has been the huge sums spent - and wasted - on venues to hold sports with little following in Greece. And yet the madness does not end there: annual 'maintenance' of the empty sites has cost almost £500million since the event.”\(^{128}\)

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\(^{127}\) China Internet Network Information Centre (CNNIC), The 22nd China Internet Development Statistics Report, published on July 24, 2008

Moreover, some Greek scholars\textsuperscript{129} have considered that the dispersed siting of these facilities and of the accompanying large-scale development of activity centered in the Athens metropolitan region has negatively influenced the development of Athens by further promoting its current sprawling pattern of development.

\textbf{3-1-4 Permanent venues: a financial albatross}

According to the latest estimate by the Beijing Olympic Game Organizing Group, the total expenditure in relation to the Olympic Games will be as high as 65 billion U.S. dollars, equivalent to 450 billion Yuan. The current total cost will be five times the cost of the 2004 Olympic Games in Athens.\textsuperscript{130}

Once, on the day of the Olympic opening ceremony, Beijing's iconic Bird's Nest National Stadium attracted a crowd of 91,000 and impressed a mass audience almost the world over through the media, but the stadium is having a hard time trying to recreate the enthusiasm more than one year after this important day. A report by the state-run newspaper China Daily on Nov. 4, 2009 called the stadium a 'financial albatross', and quoted the arena's director of research and development as saying he has to rack his brain continually to prevent the 3.6 billion Yuan venue from becoming a 'white elephant.'\textsuperscript{131}

According to a report of the China Daily, it costs an average of 200,000 Yuan per day to keep the arena running, so a few big events like the Formula One's Race of Champions event that was held the week of the report in the paper will not be enough to carry it. Last month, Mr. Zhang Yimou who was director of the Olympic opening ceremony, restaged Puccini's Turandot at the Bird’s Nest, which the China Daily report says made 6 million Yuan in ticket sales. However, the show got mixed reviews as some people said the acoustics were 'pretty good', while others said the stadium seating was awkward for many in the audience and there seemed to be technical glitches, like microphones not turning on in time. But this seems over particular about details, as it is reasonable to compare an ephemeral stage with a well-equipped concert hall with a modern indoor electro-acoustic system. Even so, whether the Bird’s Nest can earn 70 million Yuan per year to cover its maintenance cost through these commercial events, still remains to be seen.

\textsuperscript{129}Maria Zifou, et al. \textit{The 2004 Olympic Games: A Non-Planning Paradigm?}\texttt{courses.arch.ntua.gr/fsr/112805/AESOP\_04.pdf}

\textsuperscript{130}Omar UpeguiR, \textit{The Total Cost of Beijing's Summer Olympic Games}, August 3, 2008

\textsuperscript{131}Cui,Xiaohuo. \textit{Enthusiasm fades for Bird's Nest}, China Daily, 2009-11-04, Beijing
3-2 Temporary Venues may Provide an Answer

What, then, is the situation of temporary venues after the Games? There are a number of venues distributed along the north side of the Bird’s Nest in the Olympics Green. This facility group occupies a land area of 500,000 square metres. Two of the groups are temporary venues, these being the Beijing Olympic Green Hockey Stadium and Beijing Olympic Green Archery Field, both built to meet competition needs. The Stadium, which covers an area of 15,546 square metres, has a total capacity of 17,000 seats. The Olympic archery field has seating for 5,000 and covers an area of 8,609 square metres. The hockey field and the nearby Olympic archery field, covering a combined area of 21 hectares, were designed as temporary Olympic venues that would be transformed into grassed areas - the Olympic Green - after the Olympics. However, when the Olympics ended, the authorities of the Olympic Green found that removal of the two temporary venues would cost over ten million Yuan, but rebuilding would only cost three million Yuan. Therefore, the government of Chaoyang District retained the two structures hoping to transform them into a public health establishment for local sports, and that way, gradually recover the construction costs. After months of rebuilding, the functional space of the two temporary Olympic venues has been transformed into various facilities including a badminton hall and indoor basketball court, all open to the public. Because they are not standard venues, the entry charge is very low. For instance the fee charged by the basketball hall for individual use is 15 Yuan for unlimited play; for the Soccer court an individual pays 30 Yuan for unlimited play; and the badminton hall is 40 Yuan per hour. Because of these low rates, it can be predicted that the cost of reconstruction certainly cannot be fully recovered in 3-5 years.

Inexplicably, before the construction started in August 2007, it was claimed that both venues were of a “lightweight steel structure that's both easy to set up and to dismantle, thereby speeding up construction time” but what happened after the construction started was not like this. Many pictures taken from the sites and published on the official website of the Beijing 2008 Olympic Games revealed that the connections between elements and structure were mainly made by welding.

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132 The Beijing News: the nest is difficult; maintenance fee each year means raising 70 million by the Government to take over management rights, Beijing: Guangming Daily and Nanfang Daily Group
133 The Beijing Organizing Committee for the Games of the XXIX Olympiad, A lightweight structure that can be dismantled in no time. 2007-08-12, http://en.beijing2008.cn/cptvenues/venues/oga/headlines/oga/s214128956/n214131292.shtml
154a Figure Resource: http://en.beijing2008.cn/cptvenues/venues/ogh/headlines/n214074556_2.shtml
for generations call for good quality above everything else, ephemeral building does not mean lower quality but rather a different approach to the design. As long as ephemeral buildings have been carefully designed for use, engineered properly and appropriate materials selected, they can have a quality as good as that of permanent buildings. In the legacy of both the Olympics Games and Expos, there are numbers of examples regarding proposed temporary buildings being left over or finally switched into permanent buildings, the Crystal Palace being an early example.

3-3 The Future of the Hosting City

The direct financial benefits from events like the Los Angeles 1984 Olympic Games, coupled with the dramatic increase in revenues from the sale of television broadcasting rights, sponsorship by international companies, and ensuing huge tourist incomes, have brought about a growing interest from cities around the globe to host such Games. Holding an event like the Olympic Games seems to provide long term significance such as “an opportunity for massive urban renewal, urban restructuring, major environmental remediation, dramatic infrastructural improvements and the creation of a positive image across the globe. Hosting the Games is like winning the ‘gold medal’ of global inter-city competition.” However, based on the evidence presented in this thesis with regard to the urban disruption that follows the event, it is reasonable to forecast the beginning of a new phase in the development of mega events. The question that needs to be asked is why cities, both in developed and developing countries, are so interested in hosting these events. In the case of what could be regarded as world cities, the emphasis appears more on strengthening their global status in an era of growing inter-urban competition, and for those that might be called quasi-world class cities, there is probably more emphasis on the event as a catalyst for financing or realizing large-scale planned construction projects in those cities. This thesis suggests that there is another approach that could be taken to hosting sporadic events. The Black Yak Hair Tent (see chapter 6) shows that even when resources are local and limited it is possible to devise ways to make large temporary structures to hold large gatherings of people.

Driven by the economic and non-economic values of hosting a major event like the Olympic Games or a world Expo, many governments and organizations have raced to bid for events like the next Winter Olympics—Annecy, France, Munich, Germany, and Pyeong Chang, South Korea—as well as the many cities thinking of bidding for the 2020 Summer Games. This is despite the fact that some

unsuccessful games in the past have left legacies of seldom-used structures that take up valuable land and are expensive to maintain. For example, the 90,000-seat Olympic stadium in Sydney, Australia, now costs AU$30 million a year to operate. As stated above, many of the venues used in the 2004 Athens Games are either vacant or seldom used and occupy valuable land in a crowded urban centre. Besides the Beijing Bird’s Nest, the Beijing Games left a legacy of several expensive buildings, including the elaborate National Aquatics Centre (Water Cube), which is severely underused. In contrast, there are a few successful Olympic events, like the Los Angeles Summer Olympics in 1984 that have used existing facilities as much as possible, thereby making good use of scarce urban land. In another example, the stadium used for the opening and closing ceremonies in the 1996 Atlanta Games was reconfigured into a baseball stadium immediately after the games.

3-4 A Successful Legacy Lies in Planning Ahead

To deal with the fevered situation of applying for the Olympic Games (it is probably necessary to add ‘fever’ for holding an Expo or the football or rugby World Cup), Andrew Zimbalist’s advice is to “Think before you bid”, and he adds “Olympic planners need to design facilities that will be useful for a long time and that are constructively integrated into the host city or region.”

In the same way that Expos have played a key role as the catalyst for the redevelopment of their host cities, thereby contributing to their social and economic progress as mentioned before, the Olympic Games and other prime international events are often considered as having a positive impact on domestic economic development in the host countries. However, the reality of holding these events shows a wide spectrum of outcomes. If the tangible economic gains are modest, or perhaps nonexistent, what can host cities and regions do to maximize the benefits of hosting events like the Olympic Games? A careful event-specific cost-benefit analysis of past experience suggests two important ways to secure a better future. First, host cities or regions need to make careful land use decisions through a systematic feasibility study and, second, they should maximize post event use of new and renovated facilities, city and transport infrastructure, and business venues.

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135 Andrew Zimbalist is a Robert A. Woods Professor of Economics at Smith College and one of the most prominent sports economists in the land.

While urbanization has fuelled economic growth during the 21st century, it has also resulted in a huge strain on existing crowded cities and lack of physical infrastructure. Land is becoming an increasingly scarce resource both in the large urban areas that typically host the Summer Olympic Games and in the mountainous areas that host the Winter Games. Hosting the Olympic Games requires a significant amount of land for sports facilities, parking, and housing for athletes, media, staff, and spectators. The same is true for Expos. The problem is that planning for these events has been focused on the short term outcomes rather than the long term effects these events will have. Critically, to consider every possible angle in order to engage in scientific planning, a venue-management master plan is needed, well in advance of any planning and building decisions, as part of a city’s or region’s sports venue master plan.

3-5 The 2012 London Olympic Games Usher in a New Age for Venue Reuses

Apart from some inevitable Olympic hype, London did not fall into this trap in selecting the 2012 Olympic venues. Those preparing the bid took a long and very careful look at the Greater London regions’ long-term development goals. Stratford in the East End of London was picked as home to the London 2012 Olympic Games. Once being one of the poorest areas in London, Stratford and the East End region are now well advanced with a massive regeneration and transformation into one of the most livable and ecologically sustainable regions in Europe. As promised in its bid, London emphasized the fact that no permanent venues would be built unless there was an identifiable need for sporting facilities after the Games, in order to cut down on extravagance and avoid ‘white elephants’.

Almost 17 Olympic sports in London will have no bricks-and-mortar legacy by using four times as many temporary seats as in other recent Olympics. It was said that 250,000 temporary seats and 165,000 square metres of tents will be required. The reuse ability, sustainability and flexibility of these venues are summarized below.

1) The Olympic Stadium is an 80,000-seat sports complex, with 25,000 permanent seats in its permanent lower tier and a lightweight steel and concrete upper tier holding a further 55,000 spectators. The upper tier can be dismantled after the Games. The cost is £538 million and 10,000 tonnes of steel are being used to build the venue, compared to the 42,000 used for the Beijing Bird’s Nest. The stadium will also be used for other sporting, educational, cultural and community events.

2) The Aquatics Centre is a 17,500 capacity, purpose-built aquatics facility containing two 50 metre pools, a diving pool and a 'dry' diving facility. Open-water swimming takes place in the existing Serpentine Lake in Hyde Park. The cost is £244 million. The Aquatics Centre is later to be transformed into a facility for elite swimmers and the local community. Its capacity will be reduced to 2,500 but with scope for this to be increased for major events. The temporary water polo pool is to be relocated elsewhere.

3) During the Games the Basketball Arena will have 12,000 seats for the Basketball preliminaries and quarter-finals, as well as Handball semi-finals and finals, and 10,000 seats for Wheelchair Basketball and Wheelchair Rugby. The cost of this temporary venue is £60 million. The 1,000-tonne superstructure for the Basketball Arena is now wrapped in 20,000 sq m of recyclable white PVC membrane. During the Games the fabric, which is stretched over three different variations of arched panels, will act as a canvas for an artistic and innovative external lighting design. As the venue is temporary, there is no requirement for the Arena after the Games. Barr Construction will own the Arena structure, and the Olympic Delivery Authority (ODA) will ‘rent’ it from them for the duration of the Games. Afterwards, the contractor will dismantle it and remove it from the site to be reused elsewhere.

4) The North Greenwich Arena 2 used to be called the O2 Arena in the Millennium Dome. It was designed as a multi-purpose indoor arena located in the centre of the O2, a large entertainment complex, and the whole arena building takes up 40% of the total dome structure. During the 2012 Summer Olympics it is scheduled to be the venue for gymnastics, for which it will have a spectator capacity of 16,500, and for basketball finals, for which it will have a capacity of 20,000. During the 2012 Summer Paralympics it is scheduled to be the venue for the wheelchair basketball finals, for which it will have a capacity of 18,000. The cost of the O2 Arena refit was estimated in the 2004 bid to be £3 million.

5) Earls Court is an existing venue which during the year hosts hundreds of events as well as music concerts. It will be turned into a 15,000 seat arena in 2012 for Indoor Volleyball, with a capacity of 5,000. After the Games, Earls Court will go back to being an exhibition centre and music arena. The cost of the Earls Court refit is undisclosed as this is not part of the original bid.

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139 Simon Hart, (14 Jul 2009). London 2012: Olympic legacy winners and losers, the Telegraph
6) Horse Guards Parade, which hosts the annual Trooping of the Colour ceremony, is to be turned into a temporary 15,000 seat venue for Beach Volleyball. The 2004 estimated cost of the temporary structure in the bid was £5.5 million.

7) The ExCeL Centre is an existing venue for exhibitions and conferences and which rivals Earls Court for being the best exhibition centre in London. This venue will host Boxing, Fencing, Judo, Table Tennis, Taekwondo, Weightlifting, Wrestling, Boccia, Paralympic Table Tennis, Paralympic Judo, Paralympic Powerlifting, Sitting Volleyball and Wheelchair Fencing. The ExCeL Centre will be divided into 4 sports halls with capacities ranging from 6,000 to 10,000. Post Games the venue will revert to being one of Europe’s largest exhibition spaces.

8) Greenwich Park is also an existing venue. It is an enclosed royal park, with the Old Royal Naval College and the National Maritime Museum within its grounds. It will host Equestrian events (Jumping, Dressage, Eventing), Paralympic Equestrian events and the Modern Pentathlon. Temporary structures will have a total capacity of 23,000. These structures will be taken down and the park will return to the way it was after the Games.

9) Hadleigh Farm is a new 550 acre venue and is the alternative site to the original Weald County Park which was deemed not challenging enough for hosting the Mountain Bike events. Seating capacity will be3,000, not including spectators standing around the course. The temporary structures will be taken down after the Games.

10) The Handball Arena is a new, permanent venue which will host the handball games up to the quarter-final, but the semis and the finals will be played in the larger Basketball Arena. Rainwater collected from the venue’s roof will be used to flush lavatories and reduce water usage by 40%. After the Games, the structure will be adapted to become a multi-use sports centre for the community as well as a training centre for athletes and a venue for small to medium sized competitions.

11) The Hockey Centre is also a new venue. It is composed of two fields, the main field with a capacity of 15,000 and the second field with a capacity of 5,000. For hosting of Hockey, Paralympic 5-a-side Football, and Paralympic 7-a-side Football, its capacity will be 15,000. After the Games, the hockey fields will be relocated to the north of the Olympic Park, joining a collection of facilities in a place known as Eton Manor.

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140 Chris Wilson, (24 Jul 2010). London 2012 Olympics: venue guide, the Telegraph
12) For hosting the Triathlon and 10k Open Water Swim, Hyde Park will have a new temporary addition with a seating capacity of 3,000. After the Games, the course and the grandstand will be removed.

13) Lord’s Cricket Ground, is an existing venue and, in sporting terms the ‘home of cricket’ since 1814, hosting international matches on a regular basis. It will host Archery with a capacity of 6,500. After the Games, the ground will go back to being home for the Marylebone Cricket Club and Middlesex County Cricket Club. Archery equipment from the Games will be given to schools across the country.

14) The Royal Artillery Barracks date back to 1776 and are still in use. The Barracks will host Shooting, Paralympic Shooting, and Paralympic Archery. Four temporary shooting ranges will be built for Pistol and Rifle shooting, with outdoor ranges for Trap and Skeet events. Temporary seating for 7,500 will be built at a cost of £20million, the 2004 bid figure. However, recent estimates have put the final cost as high as £42million. The dismantled ranges may be distributed to shooting clubs.

15) The Velodrome is a totally new venue with two tiers, with a glass window in between the tiers for a 360-degree view of the Olympic Park. It will be host to Track Cycling, BMX, and Paralympic Track Cycling. There will be 6000 seats in the permanent Velodrome and 6000 temporary seats at the BMX track. After the Games, the BMX seating will be removed and the track reconfigured. A new mountain bike course and road cycle circuit will be added to create one venue which will encompass all disciplines in the sport of cycling.

16) The Wembley Arena is one of the most famous concert venues in the world and has been host to many of the biggest names in the music industry. For the games it will host Badminton and Rhythmic Gymnastics events with a capacity of 6,000. Post Games it will return to being a world-class concert venue.

17) The Water Polo Arena was designed to complement the appearance of the Aquatics Centre. The wedge-shaped arena will rise from 12 metres to 25 metres and feature a rippling roof made of recycled PVC cushions inflated with air to provide extra insulation. It will host Water polo with a seating capacity of 5,000. Post Games the arena will be taken down, although it is expected that its materials will be reused or recycled.

18) The Lee Valley White Water Centre is a new, permanent venue which is made up of two courses, one for training, and one for competition. It will host the Canoe Slalom and will have a capacity of
up to 12,000. Post Games the venue will remain a Canoe centre open to the public as well as elite athletes, but the temporary seats will all be removed.

From this summary the London Olympics emerge as the first time the concept of demountable building has been given a wide exposure in terms of such large enclosures. From the summary it appears that this approach offers many practical advantages. Its sustainability remains to be examined after the end of the Games through documenting and costing what happens when facilities are dismantled or converted to permanent use. There are already warning signs. Large scale construction and rebuilding of infrastructure is happening in a comprehensive way in London and the surrounding areas to complement the permanent and temporary venues. Londoners at present are keen to visit the venues or attend open day parties, but the worry is that this keenness will not be permanent. Beijing had invested a huge amount of money in its Olympic venues, which currently are far from being used optimally. Londoners may also feel some misgivings about the future of the new infrastructure and reused and permanent facilities after the games, despite all the careful planning. It has already been reported that the Aquatics Centre will cost about three times that originally estimated, totaling about £242 million. Cost increases were attributed to construction inflation and VAT increases, and also include the estimated cost of converting the facility for public use after the Olympics and Paralympics. Its roof is now stated to be 11,200 square feet (1,040 m²), a reduction from the previously stated 35,000 square feet (3,300 m²).

3-6 The Pursuit of Modest Buildings

Under the optimistic atmosphere of an economic and social boom, which could, sometime, turn out to be just an illusion, there is a certain trend for pursuing grandiose building schemes and rapid urbanization, as exemplified by the recent development of the United Arab Emirates and China. Such a mentality, divorced from reality, has tended to go in for new and large projects, often through competitions, with results that have come at a high cost. This raises the question of whether there are sufficient resources for such seemingly unlimited development. Against this trend, the exhibition of ‘1:1 - Architects Build Small Spaces’ at the Victoria and Albert Museum (V&A) in London invited 19 international architects to submit their proposals for small structures that would examine the notions of refuge and retreat. Seven of the designs were selected for full-scale construction inside the museum in 2010.
The architectural wing of the V&A as part of a comprehensive museum has a basic responsibility to explain buildings through drawings, models and photographs to the general public. In this exhibition it aimed to define built spaces as a spiritual product that is intrinsically part of people’s everyday experience, encompassing the design of buildings in which people work, eat, sleep and play. More importantly, the exhibition advocated new exploration of buildings for future cultural and social development through reflecting upon historical study. The V&A is by no means the first museum to bring an exhibition audience face-to-face with full-scale architectural commissions. In fact, both the Museum of Modern Art and the Metropolitan Museum of Art in New York have a rich history in the presentation of architectural projects. For example, Buckminster Fuller was invited to exhibit a full-scale Dymaxion Deployment Unit, a tent-like mass-production version of his 1927 Dymaxion House, in the MoMA garden in 1940.\(^{141}\)

Although the intention of the V&A exhibition was “to create a space for debate which would allow people to explore an agenda for design and construction which would return architecture to its raw state of existence - as an ‘idea’, as a basic human need for shelter – a space for retreat and contemplation on a human scale,”\(^{142}\) the opening of the exhibition could have an extraordinary influence extending far beyond architectural professionals. This is an exhibition itself not designed to be permanent but which also explores the idea of flexible building. Every opportunity is seized upon to fit buildings into existing spaces, enabling the increased use of the scarce resources of urban land. This idea needs to be extended to cover the whole city if the growing population of the world is to be fitted into its existing cities, leaving existing agricultural land untouched, for growing the food they need. The London Olympics with their plan for using existing structures, designing temporary structures for re-use and minimizing the construction of permanent structures to those that will have a post games use, is still a fairly resource intensive example of this approach since it still relies on creating new infrastructure. What needs to happen, as implied by the V&A exhibition, is the insertion of temporary exhibition and events building into existing cities to make use of existing infrastructure.

3-7 The Growing Prominence of Temporary Structures

\(^{141}\)Buckminster Fuller Institute http://www.bfi.org

\(^{142}\)Thomas, A., Retreat and Refuge - So why this exhibition, and why now?30/05/2009 http://www.vam.ac.uk/things-to-do/blogs/1-architects-build-small-spaces?page=4
Temporary construction does have some popularity in western countries. Its modern products are also mature and usually come with ancillary facilities to form a complete industrial chain, with supporting rental logistics services. In them it is difficult to distinguish permanent buildings from temporary facilities. An early example of using a temporary structure as a Summer Olympics venue is the 1932 Summer Olympics in LA. The John C. Angrue swimming stadium, as one of 15 sports venues that were used, was constructed as a temporary venue within an effort to control cost in the wake of the Great Depression in the United States. Although the equipment of this pool is showing some wear and tear, after rebuilding in March 2003 it now opens all year round with an outdoor heated pool. In addition, most venues of the 1984 Summer Olympics in LA were adapted or upgraded from existing facilities because the city was already filled with plenty of stadiums, arenas, parks and roads. Only two new venues were built specifically for the 1984 Olympics—the Velodrome on the campus of California State University Dominguez Hills in Carson, and the Swim Stadium on the USC campus.

The advantages of temporary spaces and flexible structures are embodied not only in the low energy cost in daily operation and maintenance, but also in the process of construction and material procurement. However, they achieve the same architectural function as a permanent structure. Temporary facilities and moveable buildings provide Olympic venues that still show concern for post-games reuse. They are also flexible solutions for future development, with their potential for fast installation and demolition. Most importantly, they have zero or less impact on the local environment by not using a reinforced concrete structure. The temporary facility approach has benefitted from some of the financial arrangements of the Organizing Committee for the Olympic Games (OCOG). If a permanent building with a different future function can first be proved to be a ‘Games-related’ facility then its cost could be defrayed.

As an alternative to temporary facilities, an OCOG could offer the host city the money required for the facility. Then the city can build a permanent structure. By adopting this strategy, the host city would then be able to build facilities that were more expensive, permanent, and had no follow-up usage in the sports sector but provide it at first for the Olympic usage. In Munich 1972, for example, a new trade fair hall was built which was used for judo, fencing,

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weightlifting and so on during the Olympics. A new school was erected which was first used as the MPC\textsuperscript{145} and former athletes’ village forms a new suburb.\textsuperscript{146}

Despite this support, the usage of temporary spaces and flexible structures for mega events has been beset with difficulties. This was the case with the Atlanta 1996 Olympic Games where some temporary facilities were constructed or leased. Examples of these facilities include the cycling velodrome, archery range, yachting marinas, and electrical systems at each venue. However, the organizers were criticized for the use of these temporary structures, even though the ACOG\textsuperscript{147} argued that the use of temporary facilities was often more economical on both a short and long term basis.\textsuperscript{148}

The introduction of change is usually resisted, even when the temporary solution is the cost effective one. This may be because the Summer Olympic Games are commonly considered to be the most watched event around the globe.

Four years later, in the 2000 Sydney Games, successful cases of employing a temporary structure included the 30,000 seat north-south stands in Stadium Australia, which was converted from 80,000 seats to 110,000 seats, the 11,000 seats expansion in the Sydney International Aquatic Centre and the entire temporary 10,000 seats beach volleyball site at Bondi Beach. Since 2002, most of these structures have been disassembled and incorporated into new facilities elsewhere. Because the IOC approved the procedure, this ensured normalisation and modularisation in the design, manufacture and assembling of the temporary structure components.

A noticeable feature in temporary structures is the design and construction of some movable above ground swimming pools, such as those for the 1996 Olympic Games in Atlanta, the 2004 World Championships in Indianapolis, the 2004 Olympic Trials in Long Beach, California, the 2005 World Championships in Montreal and 2006 World Short Course Championships in Shanghai. The core of this technology is a system of swimming pool construction, based on prefabricated elements made of stainless steel, and joined directly at the competition venue. These kinds of structure are classified as

\textsuperscript{145}The Main Press Centre (MPC).
\textsuperscript{146}Preuss, Holger (2004). The Economics of Staging the Olympics - A Comparison of the Games 1972 -2008 (Preface by Jacques Rogge), Cheltenham: Edward Elgar Publishing Limited, UK (Glos)
\textsuperscript{147}The Atlanta Committee for the Olympic Games
light, self-supporting, prefabricated, modular steel structures. The over-riding advantage of this system is that it is light-weight, which enables the technology to be used, for example, in the upper storeys of buildings or on weak, unstable soils, and with the ability for quick assembly. The most useful lessons from these movable pools—perhaps the greatest moral lesson—is the lesson of inherency. The generic solution offers advantages over the novel or innovative.

The wide use of this system provides a unique example from which to learn, making full use of modern technical advantages and exploring the new perspective through various approaches, which break through the traditional values of architectural design.

3-8 Temporary Structures Should not be Cheap or Lower in Quality

At the moment increasing numbers of temporary structures are giving cities and towns more unique features and are being welcomed in some crowded urban areas. They are also being accepted by the hosts of mega events. “The structures of the city that are only needed for the event, but not in the long-term, should be built as temporary in order to avoid a negative legacy.”

Today temporary constructions can avoid negative legacies such as oversized and extraneous facilities. For instance in some Olympic Games host cities like Atlanta the construction of stadiums adheres to the principle of rebuilding existing and building temporary instead of building new and permanent venues. The Beijing 2008 Olympic Games and Shanghai 2010 Expo also have massive temporary constructions, such as training grids, leisure facilities, parking lots, dining rooms, and public toilets. This lists shows that temporary urban structures can also be small in scale.

One typical example is the 27,500-seat Empire Field in Vancouver, B.C. Canada. The stadium, built to host the Canadian Football League’s BC Lions while the team’s current home, BC Place, is under renovation, will only exist in its current form until November of next year. Then, like recyclable scaffolding, North America’s first-known temporary stadium for professional football—constructed from some 15,000 parts shipped from Switzerland in 70 containers—will be dismantled and shipped back, where it will be reincarnated as another temporary sports facility. This $14 million temporary stadium contract with Nussli Special Events (Canada) was completed on time, on budget and works well. The only problem is that the temporary Field made of scaffolding has failed to create an

impression on the spectators. Contrasting it with P. L. Nervi’s work of Rome Stadium, which was
designed more than fifty years ago, reveals an enormous gap between the two structures in terms of
memorability.

A similar phenomenon can be seen elsewhere. As the third largest venue in the Olympic Park in
London and one of the largest temporary venues built for any Games, the basketball arena will cost
the Olympic Delivery Authority £60 million to rent for the Summer Olympics of 2012. However, it
was criticized because “its 'temporariness' as a structure is so evident…… it just looks cheap and a bit
like a mattress.” Generally people disapprove of ephemeral buildings if they look ‘temporary’.

Predominant mass-produced building methods such as modular buildings or demountable building
largely fail to meet the desires of people who appreciate a modernist design aesthetic, especially when
it comes to mega events. Custom-designed modernist architecture is beyond the financial reach of
many people or event organizers and so prefabrication is viewed as a design and production ideology
that has the potential to deliver affordable and delicate modernism. Maybe the methodology of Green
Design based on a kit-of-parts architecture can save the issue in a range of either "traditional" or
"alternative" forms. This in turn could have an effect in the urban environment as it would also avoid
the problem of investing in large infrastructure projects for temporary events.

150Beard, M. Portable arena for 2012 basketball to cost £60m, London Evening Standard, 2 Jul 2009
CHAPTER 4  A BRIEF HISTORICAL REVIEW OF SOME EXPOS

As one of several possible mega urban events, holding an Expo will, to a large extent, determine the profile of the host city for a number of years in the future. The first event that could be described as a World’s Fair was the Great Exhibition, held in London in 1851. Since then, a World’s Fair has been conducted in nearly 30 countries. The US hosted its first expo in New York City in 1853 with 23 participating countries. Since then, 20 large-scale world fairs have been held in 12 US cities: Philadelphia (1876, 1926), Chicago (1893, 1933), San Francisco (1894, 1915 and 1939), Buffalo (1901), St. Louis (1904), New York (1939, 1964), Seattle (1909, 1962), San Diego (1915, 1935), San Antonio (1968), Spokane (1974), Knoxville (1982) and New Orleans (1884). Although Paris is the city which has held most expos, seven in total, the United States occupies first place in the list of hosting countries in expo history. Canada has also hosted World’s Fairs in Montreal and Vancouver, in 1967 and 1986 respectively. Such a high frequency of hosting World's Fairs, has made North America a perfect model for this research into what happens to exhibition buildings after the event is over.

4-1  Exposition: Festival of the City

The earliest example of cultural and recreational activities being given a special venue of their own can be traced back to the Summer Palace on the Seine at the Paris exposition of 1878. In America, a leisure and entertainment district created as a zone with a single attribute is often called a Midway, named after the avenue of amusements at the 1893 World Columbian Exposition in Chicago. Whether at a country or state fair, this is the area where amusement park rides, entertainment, and fast food booths are concentrated. Later, exhibitions and rides created by Walt Disney and his Walter Elias Disney (WED) Enterprises company for the New York 1965 World's Fair were moved to the world-famous Disneyland after the closing of the Fair, creating a whole place devoted to these recreational activities. Many of the original 1965 rides are still operating today. From then on, recreational activities
within a reserved entertainment zone have become one of the special programs for every host city of an exposition. The public thus takes it for granted that an exposition should be full of festive atmosphere and as well as being an international showcase for trade.

4-1-1 Entertainment and expositions

“Since the mid-nineteenth century, the spectrum of entertainment architecture has been enriched by the advent of three new genres: world expositions, department stores, and amusement parks.”

Although the premier purpose of world expositions is not entertainment, the features of an Expo have evolved passively from a simple industrial production exhibition into a comprehensive urban activity. This expansion is also part of a trend that finds spending on leisure and entertainment increasing as never before. In turn, a variety of leisure facilities have also been brought into the fair pavilions. In addition, entertainment venue, parks and green space, together forming a themed park-type activity, are often seen as one of the key parts of an Expo.

Functionally architecture expressive of entertainment normally applies to some forms of building for pleasure such as the Colosseum, the Sony Centre, Las Vegas, Disneyland, Celebration, Coney Island, the Mall of America, Sentosa, the Wembley Stadium, the Palm, and Tropical Island. Entertainment architecture in its narrow sense is supposed to be the architecture of theatres and amusement parks. However, the term can refer to any kind of building or structure, regardless of its function, as long as it is designed to stimulate both imagination and creativity, afford enjoyment and encourage fantasy. The predominant characteristic of entertainment architecture can be easily recognized through its visual aspects, such as playful re-creations of famous monuments, enormous statues and fountains, and some stylistic features, such as elements of postmodernism.

4-1-2 The attributes of Expo buildings

An Expo building is not only built for the purpose of living out a fantasy or for pure pleasure. Even in recession an Expo and its buildings may serve as an economic boost to its community or even as a site for escapism for some people. As discussed later, Vancouver is an example of a place that grew in wealth and significance as a result of its Expo. Most Expo buildings have both an enlightenment and financial function. So defining an exposition building as entertainment architecture is not very appropriate. This is borne out at Seattle where the legacy of the Alaska-Yukon-Pacific Exposition in

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1907 has partially shaped the campus of the University of Washington, which is not a function often associated with entertainment.

Films, television programs and computer software now dominate the public entertainment arena but are often combined with education. The same could partially be true for Expo buildings. Having large displays in an exposition building is likely first to be treated as proof of a nation’s financial position and strength. Expo buildings are places to show products but this “showing” can still be seen as entertainment. This entertainment character of the buildings will be continued after the main use of the venues has stopped. At the same time, the intention to educate people at a world exposition is not the main attraction for the majority of organizers, as pushing education could reduce people’s interest in attending and lower ticket incomes. A few professional visitors may come for educational reasons or business opportunities, but hundreds and thousands of people, especially the younger generation, pay for the ticket because they are looking for some kind of fun or delight. Unmitigated didacticism will probably blight an exposition.

Furthermore the architecture of exposition buildings could fall into the category of festival architecture that has “brought vivid colour and sensory delight to the cities.”  

154 Ibid.

“Festival architecture, throughout the ages, has allowed architects to experiment with new ideas, new forms and new spatial arrangements.”  

The architecture of buildings for exposition and entertainment is different, but they are closely related to each other. Practically, world fairs are just like super stage performances for certain celebrations or festivals and exposition buildings are varied settings for special occasions. Performances are a type of entertainment that deliver dramatic effects to audiences through aspects like inflated dialogue, costuming, stage lighting, and music. However in some circumstances stage sets cannot be too exaggerated otherwise an audience may think the performance is not realistic. Settings (exposition buildings) in particular have to be effective enough for transporting spectators into the desired mood and impression. So exposition buildings are not the full equivalent of entertainment architecture, but have attributes of normal buildings as well. This is a crucial point to keep in mind for expo event organizers.
Nowadays, holding a large-scale international exhibition and conference is considered to be a major factor in establishing the position of a country in the family of nations, in terms of either prosperity or worth. Thus far a large number of pavilions and arenas have been, or are being built, for a wide variety of major events such as the World’s Fair, an Expo, or the Olympic Games. These constructions normally consume a high percentage of the host city's resources and energy. To eliminate or stop these resources being wasted, the life of these facilities has to be prolonged or augmented. A crucial issue is how to maximize the reuse or redesign of buildings that could be conceived as “white elephants” once the exhibition is over. One of the best solutions for a temporary exposition building is transformation of its function from exposition into entertainment. Because of the complexity of different requirements, some exposition buildings may have single attributes and some may have multiple attributes. For most exhibition buildings an integrated and sustainable planning or design process would be needed. That means creating a multi-functional design that would be suitable for future transition of use instead of a purpose-made design only suitable for the single occasion. Even for a single attribute building its transition can be achieved by consideration of what happens to it later or through reservation in design that makes such a transition possible.

4-2 Exposition: Catalyst to Promote Urbanization

Out of the 21 large-scale world fairs held in North America, most encountered economic predicaments or had some financial embarrassments before, during or after the exposition. Among them the World's Columbian Exposition held in Chicago in 1893, the San Francisco Midwinter Exposition of 1894, Buffalo’s Pan-American Exposition of 1901 and the Saint Louis World's Fair of 1904 were all the product of difficult times. The nationwide economic depression in the USA originating from the late 1880s meant that there were tough times for expositions especially in Chicago. Before this, Chicago had suffered from the great Chicago fire, which had destroyed much of the city in 1871. Under such circumstances, the majority of the Exposition's grand and different exhibition palaces were temporary structures, only designed to last a year or two at most. They were built with a material called "staff," a mixture of Plaster of Paris and burlap fibre, on a wood frame. Many of the buildings and statues deteriorated during the progress of the exposition, and had to be patched. Afterwards other fair buildings, such as those at both the San Francisco Panama-Pacific International Exposition (PPIE) in 1915 and San Diego’s Panama-California Exposition in 1915 were temporary structures. As the main purpose of the PPIE, which followed the 1906 San Francisco earthquake and fire, was to showcase its recovery from the disaster, it was not a surprise when archival research for this thesis
uncovered some unopened site pictures at the San Francisco History Centre which showed buildings, including the Palace of Fine Arts, which were constructed like stage settings. Almost all this fair’s various buildings and attractions were pulled down late in 1915. The only surviving building from the PPIE, the Palace of Fine Arts, slowly fell into disrepair. The Palace, including the colonnade with its signature weeping women and rotunda dome, was completely reconstructed in the 1960s and is currently occupied by the Exploratorium, an interactive science museum. The architecture of the "temporary buildings" was recognized by Bertram Goodhue\textsuperscript{155} as “being essentially of the fabric of a dream — not to endure but to produce a merely temporary effect. It should provide, after the fashion that stage scenery provides — illusion rather than reality.”\textsuperscript{156}

Generally speaking, the majority of structures built for a World’s Fair is temporary and are dismantled at the end of the expo. A major exception is the Eiffel Tower, built for the Paris Exposition Universelle (1889). Other outstanding exceptions are remnants from Expo '29 in Seville, Spain, where the 'Plaza de España' forms part of a large park and forecourt, and many of the pavilions have become offices for Consulate-Generals. In Brussels, the Atomium still stands on the site of the 1958 exposition. The Space Needle in Seattle was the symbol of the 1962 World's Fair, and the US pavilion from that fair became the Pacific Science Centre. San Antonio kept the Tower of the Americas intact, together with the Institute of Texan Cultures and the Convention Centre after the Hemis Fair of 1968. The Sunsphere remains extant from the 1982 World's Fair in Knoxville. The Museum of Science and Industry in Chicago is housed in the last remaining building of the 1893 World Columbian Exposition, which had been the Palace of Fine Arts. The intent was to make all Columbian structures permanent, but most of the structures burned down, possibly as the result of an arson attack during the Pullman Strike. The World Heritage-listed Royal Exhibition Building in Melbourne which was constructed for the 1880 Melbourne International Exhibition is another example of a building built for a fair which still has a use.

One of the most intact transformations from temporary architecture into a permanent development is Balboa Park after both the 1915 and 1935 expositions. With the landscaping, San Diego Zoo and buildings built for the fairs, the park is now a southern Californian cultural cluster, housing many of

\textsuperscript{155}Goodhue was a New York architect, chosen as supervisory architect for the Panama-California Exposition (1915). Goodhue advised use of the more varied Spanish Colonial architecture at the fair, and saw the exposition as an opportunity to create a fantasy city.

San Diego's major museums. Balboa Park is a successful model of sustainable development in the urban context of San Diego. New York City was also left with a good suburban park—Flushing Meadows Corona Park—after the 1939 and 1964 World's Fairs.

Prior to 1939 the park was a massive dumping ground for ashes. Parks Commissioner Robert Moses and other city planners laid out an elaborate scheme to replace these ashes with beauty and excitement. They proposed transforming the site into a World's Fair. A substantial percentage of the fair's profits were to be allocated toward the creation of Flushing Meadows Corona Park. Unfortunately, the 1939 World's Fair failed as a financial venture, leaving the dream for a park unrealized. Subsequently, the site stood largely idle until the early 1960s when a new World's Fair Corporation formed to sponsor a sequel to 1939, with Robert Moses again at the project's helm. Like the first one, the 1964 Fair failed to yield profits, but it left behind several prominent structures which have provided a foundation for the unique urban oasis Moses had envisioned.

Besides serving as a fairground for two expositions, the park was host to the United Nations General Assembly for five years, three baseball World Series at Shea Stadium, and the U.S. Open at the USTA National Tennis Centre. Increasingly, it is becoming a recreational and athletic hub for two completely separate ethnic communities, the Asians of Flushing and the Hispanics of Corona in New York City. Queens County, where the park is located, is the largest in area and the second most populous of the five boroughs of New York City. While Manhattan residents take ownership of their beloved Central Park, Brooklyn has Prospect Park and the Bronx has Van Cortlandt, the second most populous borough in New York City with a population of 2.2 million has Flushing Meadows Corona Park.

The period of the Great Depression, from 1930 to 1940, is a prime example of a macroeconomic crisis that produced adverse economic and social effects on all aspects of world expositions. The primitive motivation for holding the expositions of San Francisco 1939, New York 1939, San Diego 1935 and

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157 Robert Moses (1888–1981) was the master builder of mid-20th century New York City, Long Island, and Westchester County, New York. As the shaper of a modern city, he is sometimes compared to Baron Haussmann of Second Empire Paris, and is one of the most polarizing figures in the history of urban planning in the United States.

158 New York City Department of Parks & Recreation, About the Park - Flushing Meadows Corona Park.

159 U.S. Census Bureau, County and City Data Book:2007 Table B-1, Area and Population, retrieved on July 12, 2008. New York County (Manhattan) was the nation's densest-populated county, followed by Kings County (Brooklyn), Bronx County, Queens County and San Francisco, California.

160 American Fact Finder (U.S. Census Bureau): Table GCT-T1, 2007 Population Estimates for New York State by County.
the 1964-65 New York World's Fair was to push the economies of the various cites forward and reclaim their vitality. While the 1984 Louisiana World Exposition in New Orleans was a financial failure, being neither a model of organization nor of content, it nevertheless was a useful urban redevelopment vehicle for this riverside city. It left a series of improvements to downtown New Orleans, such as the Riverwalk, revitalization of the Old Warehouse District, and the Marketplace and Building 1 of the Ernest N. Morial Convention Centre that together support the city’s tourist and convention business.

The process of a city’s development is often long and sometimes erratic. Hosting an Expo can catalyze the process and accelerate the speed of urban renewal, redevelopment, restructuring, repositioning or whatever is good for the host city’s infrastructure. Sometimes this process is like a reversible chemical reaction, the higher the urbanization of the city, the easier it is to win an expo bid, but the expo process can help cities to grow and societies become more urban.

4-3 Three Hosts that Have Benefited from an Expo Legacy
Trying to better illustrate how a host city has benefited from its expo legacy through the approach taken with its events buildings, three expos have been chosen for a detailed analysis in this thesis. All three examples deserve to be called successful expositions no matter whether they are viewed from cultural, financial or social angles.

4-3-1 Alaska-Yukon-Pacific Exposition’s legacy to the UW campus
Seattle is best known for the six month Century 21 Exposition in 1962, but had a much earlier experience of holding a regional world's fair in 1909. This was the Alaska-Yukon-Pacific Exposition (AYPE) publicizing the development of the Pacific Northwest. It was originally planned for 1907, to mark the tenth anniversary of the Klondike Gold Rush, but the organizers discovered that the Jamestown Exposition was being held that year, and rescheduled the AYPE to 1909.

The primary tangible legacy left by the AYPE is the planning intrinsic to the fair which continues to shape the University of Washington (UW) campus. In 1905 the University had only three buildings and little deliberate landscaping. Based on what the landscaping and structures of the 1909 fair could do for the campus, Edmond S. Meany, its proposer, eventually sold to the others involved the idea that
the forested campus could, itself, be an attraction for out-of-town visitors. As a professor of botany and history at the University of Washington, Meany’s opinion certainly had a great influence on the landscaping for the AYPE and subsequently the UW. Finally the state legislature endorsed the fair, with the proviso that it would produce at least four permanent buildings, and that any state monetary contribution would be mainly focused on those buildings.

Although most of the AYPE buildings were designed as temporary structures, intended to last only for the duration of the exhibition, some were more permanent.

> When the Exposition ended in October 1909 the University received 25 buildings plus the streets and other improvements that had been made for the Exposition. These included the Geyser Basin, now Drumheller Fountain. The 25 buildings included three that were intended to be permanent additions to the campus plus others that were adapted as academic buildings; the Washington Building, e.g., became the Library. Fifteen buildings were used for various auxiliary purposes, such as the New York Building, which became the president's residence, and the Hoo Hoo House, which became the Faculty Club. Since most of the buildings were not intended to be permanent they began to deteriorate rapidly.

According to the University of Washington Libraries Digital Collections, the Rainier Vista and Drumheller Fountain, the focus of the AYPE, are today the central focus of the Science Quadrangle of the university's overall plan. The Fine Arts Palace was designed by Howard and Galloway as a chemistry building, although it was used during the AYPE for the exhibiting of artworks. After the AYPE, chemistry lab tables and other furnishings were moved in and it became the University's primary facility for teaching chemistry. The building was named "Bagley Hall" (after Daniel Bagley) and retained that name until 1937, when a new chemistry building named "Bagley Hall" opened. The older building then became the home of Architecture and Physiology. The building survives today and is known as Architecture Hall. The AYPE Women's Building also survives. During the AYPE it housed exhibits related to women. Today the building is named Cunningham Hall (after Imogen Cunningham), being one of only a few buildings on the University of Washington campus named after women.

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163 Bagley, Daniel (1818-1905), a printer, publisher, and writer, was a founder of the Washington State Historical Society, and the region's first and preeminent historian.
During the AYPE the building was finished in stucco; today it is faced in wood siding. The building now houses various educational and other programs related to women.

4-3-2 Century 21 Exposition’s legacy: the Seattle Centre

Like the 1909 fair, the later Century 21 Exposition was planned with the same purpose of reuse after the event. It left behind a fairground and numerous public buildings and public works. Some people have credited it with revitalizing Seattle's economic and cultural life. “The world’s fair reenergized the downtown of Seattle, and was generally a smashing success, even finishing with a profit.”165

The fair saw the construction of the Space Needle and Alweg monorail, as well as several sports venues and performing arts buildings (most of which have since been replaced or heavily remodeled). The site, slightly expanded since the fair, is now called the Seattle Centre. One building that has survived, the United States Science Pavilion, is now the Pacific Science Centre. Another notable Seattle Centre building, the Experience Music Project, was deliberately designed to fit in with the fairground atmosphere left by the fair, although built nearly 40 years later.

The Seattle Centre is based on the legacy of the Century 21 exposition and has become one of the chief attractions of Seattle. The Centre deals in entertainment with 63 free and low cost public programs and over 5,000 shows and events annually. The 74-acre campus, with its 17 acres of open space, is welcoming to all, and is home to more than 30 cultural, educational, sports and entertainment organizations. This treasured urban gathering place exists to delight and inspire people and bring a rich and varied community together. The 12 million visitors to the Seattle Centre each year generate $1.15 billion US in business activity and $387 million US in labour income for King County.166

In fact, this fair’s theme was originally conceived as a “Festival of the West,”167 with the aim of producing benefits for the downtown area of the city through more diverse economic activity. A main reason for holding the fair, officials explained during the late1950s, was to “build a more diversified

165Shear, E., Seattle: Booms and Busts, Study of the City - Spring 2002, History of Seattle – Yale University
166Seattle Center Mayor’s Task Force for Seattle Center for Sustainability, Seattle Center Financial Summary, May 2006
167Lesson Twenty-five: The Impact of the Cold War on Washington, The 1962 Seattle World's Fair, Center for the Study of the Pacific Northwest, University of Washington
industrial economy” that would reduce the region's “heavy reliance…on defence spending by the Federal Government.”

Then in October 1957 the subject matter of the fair was decided for the civic leaders in Seattle when, in one of the crucial moments of the Cold War, the Soviet Union launched the first artificial satellite in the world. By taking the world by storm, Sputnik-1 had become a subject of great topical interest. American officials were eager to convince the nation and the world that the United States was not really behind the Soviet Union in the realms of science and space and the fair offered the opportunity to do this. As the most important and influential power in the region, Boeing wished the fair to be an absolute monument regarding space and aircraft.

Although Boeing dominated the themes of the fair, science and space were perceived as a universal language and astronaut John Glenn's Friendship 7 was the most popular part of the fair's NASA exhibit. Despite these activities, under the insistence of civic leaders in Seattle the tone of the exposition was kept to produce the atmosphere of a scientific carnival. This in turn ensured a successful transition for the site of the Century 21 Exposition to become the Seattle Centre afterwards.

Today wandering around the Seattle Centre, people can still feel that there is something like a fete or carnival in the air. Indeed with the clamour of the monorail, the screams from the kids on the rides, buildings designed with gorgeous colours, smells from fast food booths, and of course the Space Needle like a flying saucer in the sky, the place is still exciting and somewhat overwhelming. Practically, the most successful thing to emerge for the city would be the Century 21 Exposition’s rebuilding of ‘greyfield’ land into a very popular science complex. Unlike some other World's Fairs of its era, Century 21 produced a profit.

4-3-3 Expo 86 lifted Vancouver to be a world class city

Stepping off the aero plane and walking into the city of Vancouver in May 2008, even at the airport, immediately it was possible to feel that the Olympics were coming. From the banners in the sky to the posters on the ground, there were signs of the Games everywhere. Talking with Vancouver locals regarding the topic of the Olympics, from ordinary people to the officers of the Vancouver Organizing

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Committee (VANOC) for the 2010 Olympic and Paralympics Winter Games, “You will see…” were their first words. It was pretty certain that everyone had a deep personal pride in what was happening but where did the confidence come from?

The source of Vancouver’s confidence can be traced back to the experience of hosting the 1986 World’s Fair with the theme of "Transportation and Communication: World in Motion - World in Touch," or simply Expo '86 which was held on the north shore of False Creek of Vancouver. It was also the city’s centennial on April 6, 1986. As the most significant international event ever on Canada’s west coast, the 1986 World Exposition was the last World's Fair held in North America and was considered a success, receiving 20,111,578 visitors. Several Vancouver landmarks date from that period, including the Sky Train public transit system, the Plaza of Nations, and Canada Place.

Vancouver was created in the 1880s partly as a western terminus for the Canadian Pacific Railway (CPR). Lumbering, mining, fishing and whaling were the early industries in the area. After the opening of the Panama Canal in 1914, Vancouver’s seaport was able to compete with the major international ports for global trade because it was positioned as an alternative route to Europe. From then on, prairie wheat came west through Vancouver instead of being shipped out through eastern Canadian ports. By the 1930s, commercial traffic through the port had become the largest sector in Vancouver’s economy.\(^\text{170}\)

Vancouver’s natural geographic features are unique in western Canada. From the point of view of history, Vancouver was once a resource gathering area for food and materials for the indigenous peoples of the Pacific Northwest Coast. The Fraser River which is the longest river in British Columbia, passing along the southern shores of Vancouver, separates the cities of Surrey, Richmond, and Delta from the city of Vancouver proper. The indented coast line contains many bays, such as

False Creek, Horseshoe Bay, Lions Bay, and English Bay. These bays interrupt the normal land connection and have caused many transportation problems. For efficiency in road building the scattered land areas of the city had to be connected to each other, so the Vancouver authorities always concentrated their attention on infrastructure. First of all, the Second Narrows Bridge and the Lions' Gate Bridge established a link between Vancouver and the North Shore, dating from 1925 and 1938 respectively. The Oak Street Bridge opened in 1957 and connected Vancouver to Richmond across the Fraser River. The Ironworkers Memorial Second Narrows Crossing followed in 1960. Another major bridge across the Fraser River, the Port Mann Bridge to Surrey, opened in 1964. The continuing growth of the Vancouver International Airport on Sea Island in Richmond resulted in the construction of another bridge across the Fraser River, the Arthur Laing Bridge which was opened to traffic in 1975.171

Making the earliest connection with eastern Canada, Vancouver was selected as the western terminus of the transcontinental railway by the Canadian Pacific Railway (CPR), and this was a condition of British Columbia joining the confederation in 1871. Besides the railway, the four western provinces part of the Trans-Canada Highway begins in Victoria, British Columbia, whence it passes through the Vancouver metropolitan area, heading 170 km east to Hope. This is the world's third longest national highway, with the main route spanning 7,821 km and linking all ten provinces of Canada. The Trans-Canada Highway makes road transportation easy from the Pacific coast cities to the Atlantic coast cities. Its construction commenced in 1950 and officially opened in 1962, and it was completed in 1971.

After the most important infrastructure works were in place, Vancouver made its first attempt at holding a World’s Fair in 1974. Five years later British Columbia formally filed an application for holding an Expo and the IBE approved it in principal on November 29, 1979. As one report states, “Vancouver won the bid for Expo '86 during a major recession in British Columbia, as resource industries were being ravaged by global restructuring processes.”172 In the late 1970s, the 173 acre (0.7 km²) brown field site in False Creek, where Expo '86 was staged, was a former CPR marshalling yard with the expectation it would be redeveloped as a commercial and residential district. By the early 1980s, as the project developed in more detail, all kinds of conflicts were raised.

172 Antonio Azuela, Emilio Duhau, Enrique Ortiz, Evictions and the Right to Housing: Experience from Canada, Chile, the Dominican Republic, South Africa, and South Korea, International Development Research Centre (Canada), 1998
Opposing agendas did not correspond. Cost estimates skyrocketed and land disputes on the proposed rapid transit line erupted. Negotiations over which level of government was obligated to pay for certain projects and potential deficits escalated to such a heated pitch that the Provincial government cancelled the World’s Fair in 1981. It was a surprise to the public four months later when the Provincial government announced that Expo ’86 would go ahead as scheduled and the Federal government agreed not only to build the largest Canada pavilion ever erected but a new cruise ship terminal at Pier BC as well. A lottery was established to help pay for the cost of Expo ’86, and a short time later, the first working site model was unveiled to the public.\footnote{http://www.geocities.com/exposcruff/history/history.html}

Construction started in October 1983, and Expo Centre opened on May 2, 1985 as a preview centre for the fair. The final cost of the fair ended up being CAD$8 million under budget. The site featured the pavilions of 54 nations and corporations. Expo's participants were given the opportunity to design their own pavilion or opt for the less expensive Expo module. Each module was approximately two-and-a-half storeys high and had a floor space equal to a third of a city block. The design was such that any number of the square modules could be placed together in a variety of shapes. The roof design allowed the interior exhibition space to be uninterrupted by pillars. Importantly for this thesis, this was first use of pavilion modules at a World’s Fair.

The construction phase officially ended one month before opening day, and Expo ‘86 opened on May 2, 1986. Vancouver had reason to be proud. Compared with a prediction of 13.7 million people visiting the fair, by the end 22 million people had attended the Expo and, regardless of a deficit of CAD$311 million, it was considered a tremendous success. It remains to date the largest event in the history of British Columbia and is viewed by many as the transition which brought Vancouver from a sleepy provincial backwater into a city with some global standing, as well as providing a strong boost to tourism for both the province and western Canada.

After serving as the venue for Expo ‘86, the western half of the False Creek area continued to be developed into parks and high-rise condominiums. The eastern portion was used for the site of an annual car racing event, until this was cancelled in late 2004. Future plans call for the eastern third of False Creek also to be developed into parkland and condominiums. The western third of the site was
auctioned and is presently owned by the real estate development team Concord Pacific, with its primary shareholder the Hong Kong billionaire Li Ka-Shing. The redevelopment of the False Creek site took longer than the expected 30 years planned, but is one of the most successful urban developments in Canadian history. The south eastern section of the site, just underneath the former Expo Centre, is being developed for use as part of the Olympic Village for the 2010 Winter Olympics and as waterfront park land. Now (at the time of visiting as part of this research investigation) both of these developments are under construction.

The Plaza of Nations, one of the last remaining structures from the fair, was used as both an outdoor and indoor venue for public gatherings and concerts. After twenty years, the glass canopy that connected it to the adjacent office buildings was found unsafe and torn down. The two office buildings are now also undergoing complete demolition, leaving Canada Place and the Telus World of Science as the only remaining structures directly left from the Expo site. The Expo Line of the Sky Train is one of the longest automated light rapid transit systems in the world and has been expanded several times since it was first built (Fig.4-2).

BC Place, built as part of the preparation for the 1986 World's Fair in 1983, is an indoor stadium which is still busy, with over 200 event days per year, contributing over 40 million Canadian dollars (CAD) per year in economic benefits to the Province of British Columbia. However, it operates at a loss of more than 4 million CAD a year (10 million in earnings but more than 14 in expenses), not including 2.3 million CAD for amortization. It hosts the Province's largest trade and consumer shows, community events and motorsports. A budget of over CAD$150 million was announced for major renovations to the stadium, including seat replacement, renovations to washrooms, and concessions. Most renovations will be completed prior to the 2010 Winter Olympics. Another direct contribution to

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174 The SkyTrain is a two-line urban mass transit system in Metro Vancouver, British Columbia, Canada. There are now 2 lines in operation, 1 under construction, and 2 being planned. The Expo Line, being the first started in 1985, was built in time for the Expo 86 World's Fair.
being a world class city from the Expo was the increase in Vancouver’s population (Fig.4-3). According to census data of Statistics Canada, taking 1976 to 1996 as the observation period, the percentage population increase was a steady rate of about 8% for a 5 year period from 1981 to 1986, but soared to almost 21% for another 5 year period from 1986 to 1991 after Expo’86.

All the above mentioned structures and facts are the legacy left by Expo ’86, which is considered to have been the foundation for Vancouver to become a “world-class city.” There are no uniform standards for a world-class city. As Bill Virgin has said: “Some cities count as world-class not just because of their size but because of their importance in business, finance and government, or all three—the Londons, New Yorks, Tokyos and Shanghais of the world. Others count because of a concentration of a particular industry—Detroit for automobiles, for example, or Los Angeles for entertainment.”

Vancouver, however, does not have the same qualities for being a world-class city as New York, London or Tokyo.

_The economy of Vancouver has more traditionally relied on British Columbia's resource sectors such as forestry, mining, fishing and agriculture. It has diversified over time, however, and Vancouver today has a vibrant service industry, a growing tourism industry, and it has become the third-largest film production centre in North America after Los Angeles and New York City, earning it the nickname Hollywood North. Vancouver has had an expansion in high-tech industries, most notably video game development._

The advantages of Vancouver mainly come from its geographical location as a gateway to the Asia Pacific region. Functionally, the five cities of San Francisco, Los Angles, Seattle, Portland and Oakland on the Pacific coast work for the United States the same as Vancouver alone does for Canada. Moreover, BC tourism statistics have pointed out that Expo ’86 as a catalyst played an important and key role in boosting the tourism industry. Tourist revenue is now a major part of the provincial economy, second only to the forestry sector, and it is larger than mining, agriculture, and fishing in BC. The following data may give a clear picture of this.

_During the Expo year, 1986, British Columbia attracted 68% additional international visitors to the province, (more than 2.8 million), on top of a solid 6% gain the previous year. In the first post-Expo year, 1987, the province gave up most of the Expo gain but retained a 14% increase_

BC Statistics also show that Expo 86 started its planning 6 years in advance resulting in a tourism increase from CAD$1-$9 billion during the period 1972-2000. Vancouver is becoming one of the world's top travel destinations.

Additionally, if house prices are used as an index for world class city status, as some real estate dealers consider, Vancouver has become a substantial member of the ranks of world class cities in North America since the beginning of the 21st century. The average two-storey home in Vancouver sells for $757,750, compared with $467,742 in Toronto and $322,853 in Calgary, the next most expensive major cities in Canada.\footnote{Economics/Research. Royal LePage, (29 March 2007), Survey of Canadian Average House Prices in the First Quarter 2007 (PDF).Retrieved on 2007-04-11.} In 2007 according to Forbes, Vancouver had the 6th most overpriced real estate market in the world and second in North America after Los Angeles.\footnote{Woolsey, Matt (2007-08-24). World’s Most Overpriced Real Estate Markets. Forbes.com} An overpriced housing market may not a good thing for a healthy economy but it reflects the fact that Vancouver has been attracting more and more people to move in since Expo’86.

Despite this boost to the economy the direct Expo ’86 legacy was a deficit of CAD$311 million. However, it would have cost much more than that to build the much needed structures including the infrastructure for the 2010 Winter Olympics from scratch. So indirectly the Expo will contribute to what should be Vancouver’s next success which is the forthcoming 2010 Winter Olympics (forthcoming at the time this part of the thesis was written). Any construction of mega buildings or infrastructure additions to a city always takes a considerable quantity of tax dollars and time. From this point of view Vancouver has gained enormously from Expo’86 in terms of confidence and experience as the basis for hosting new global events. This was absolutely proved by an interview with Mr. Neil Turner, Director, Environmental Approvals and Management, Vancouver Organizing Committee for the 2010 Olympics and Paralympics Winter Games (VANOC). As he indicated, early in the process VANOC evaluated the experience of Expo ’86. There were also a number of VANOC
staff who worked for Expo ’86, and their experience was very important for the preparation work. New venue construction has also taken full consideration of the pros and cons learned from the former Expo’86. Energy saving and environmental protection are the two top considerations for the new Olympic buildings, all of which have to meet LEED\textsuperscript{180} standards, together with an after-games reusable requirement. The Community Centre of the Olympic Village on the south shore of False Creek is intended to reach the rating of LEED Platinum while other buildings in the village will be LEED Gold. After both the competition sites in Vancouver and Whistler were visited as part of the field work for this research the most clear impression left was that the pivotal line of venue construction has been shifted away from bombastic architecture such as towers and monuments toward more conservative structures that could be reused in the future, which seems absolutely right in the current global environment. The Vancouver Olympic Centre is a good example. This venue is in the geographic centre of Vancouver (Ontario St. and 30th Ave.) that includes the beautiful Queen Elizabeth Park and views of the local mountains. After the 2010 Winter Games, the curling venue will become a multi-purpose community recreation centre that will include an ice hockey rink, gymnasium, library and six to eight sheets of curling ice. Attached to, and being constructed with the new curling venue and community centre, is a new aquatic centre with a 50-metre pool and leisure pool for the residents of Vancouver.

The whole recreation complex was supposed to meet the LEED Gold standard. Parts of special consideration for a green and sustainable facility are as follows: new facilities to replace aging existing community complexes, and new complexes located on former gravel parking areas represent a good site selection; overall consolidation of venue footprints, revised from early designs, will reduce land impact; re-vegetation of demolition sites during conversion will result in target net zero green space loss; obstructing trees have been relocated to other sites within the park; no net loss of playing fields resulting from site redevelopment; use of waste heat from the refrigeration plant to heat other buildings and the adjacent aquatic centre; and use of materials with recycled content, regional, and sustainable materials for new construction such as the Glulam beams used in the aquatic centre. Vancouver is striving to be an economic capital, a social capital and a natural capital as part of its long-term sustainable development. It was reported that Vancouver was doing a feasibility study for the 2024 Summer Olympic Games co-operating with the city of Seattle. If Expo’86 initiated

\textsuperscript{180}LEED is a North American rating and certification system that evaluates energy performance and sustainable building practice with four levels of certification - certified, silver, gold, and platinum.
Vancouver’s move to be a world class city, then hosting the 2010 Olympics and Paralympics Winter Games presented an exciting challenge and opportunity for being a green or sustainable world-class city, something which can be considered of pivotal importance to the world. At the time this was written, people were looking forward to seeing a greener and sustainable Winter Olympic Games in 2010.

4-4 Toward Sustainability: From Osaka Expo '70 to Aichi Expo '05

According to the Bureau International des Expositions, an organization that governs the legislation of international exhibitions, all expos can be divided into two categories: registered and recognized expositions. Osaka's Expo '70 and Expo 2005 Aichi were two Universal Expositions (registered expositions). If the Special Expositions (recognized expositions) of Okinawa's Expo '75, Tsukuba's Expo '85 and Osaka's Expo '90 are also counted, Japan has held five expositions in the history of world expos. Among them, Expo '70 Osaka demonstrated Japan’s economic progress and nation revitalization, while Expo 2005 Aichi reflected the national determination to develop a new life for the 21st century.

4-4-1 Expo '70 Showcases Japan to the World

Japan held its first world's fair (Expo '70) in 1970 in Osaka. It was a tremendous hit with a world breakthrough in the number of visitors, amounting to 64,210,000 people. In 1970, Japan's population was about 104 million so the visitor total was almost half of the then population of Japan. In Japan, Expo '70 is often referred to as one of the largest and best attended expositions in world expo history.

To host Japan’s first world expo, the city of Osaka and the Japanese government invested huge capital in the construction of a new transport system and the reconstruction of the existing system. The high-speed railway from Tokyo to Osaka was reconstructed, Osaka airport was expanded, and several dozen kilometres of railroads from the city centre to the fair site were laid. All of these greatly facilitated visitor travel. The result was the Osaka world expo secured a profit of 17 billion yen. After Expo '70 these funds were used for the establishment of both the Osaka World Expo Memorial Park and the Japanese Association of World Expos Memorial, which have since played an important role in

181 Abbreviated as BIE
all kinds of cultural exchange activities. All subjects at Expo’70 followed the Expo theme of “Progress and Harmony for Mankind.” The idea behind this was to prompt mankind to make better use of natural resources, better use of science and technology, and to better promote mutual understanding and better enjoyment of work and life.

Under Kenzo Tange’s design concept entitled “Grand Festival of World Culture”, the physical form of the Expo mainly followed that of former World’s Fairs such as New York in 1964, Seattle in 1962, and Montreal in 1967, but attention was given to the spiritual life of humanity with a Japanese flavour. There were 116 different pavilions in the expo’70 venue. Architects from all over the world used their rich imaginations to make the buildings the most up-to-date and advanced showcases. To break the traditional mould, the buildings were dominated by the expression of technology as an ideological trend. The Pepsi Pavilion (Fig.4-4) is one such example. It is a multi-media theatrical space and interactive environment with high-tech displays and has come to be known as one of the most ambitious and groundbreaking collaborative art and technology projects of the 20th Century. Many pavilions and facilities made reference to Archigram, Britain's futurist fantasy architectural group as discussed above. Architects, whether from Japan or other participating countries, embraced the perspective of the future city and widely used steel, glass, and new materials such as Mylar plastic sheeting, as found on the US Pavilion roof (Fig.4-5). This roof covering consisted of a fine-thread fabric of close-woven glass fibres, coated on both sides with vinyl to provide air and water tightness. All of the pavilions used these materials in ways that emphasized current modern architectural trends. This was something that permeated other Expos after the Second World War and may well have been started by the emphasis placed on technology and futuristic imagery in some of the buildings of the 1951 Festival of Britain in London, such as the Skylon Tower and the Dome of Discovery.

Showcasing the theme and spirit of innovation, some strange and different forms of construction for the halls produced a direct visual impact and attracted attention through their novelty. Among them the Takara Beautilion (Fig.4-6) was peculiar and different from the others. Constructed using a space frame with a cubic multi-layer grid, it was assembled from rigid jointed modules that were bolted together on site, and these prefabricated units were put together in one week.
The four-storey framework of the upper structure was composed of steel preformed units bolted together. Twelve curved steel pipes were attached to each other to form a cross horizontally and vertically. A steel panel was then welded to the curved part that formed the center of the cross, turning the pipes into a unit. These units formed a tree structure stretching out in all directions. This frame structure is characterized by its potential to be extended or replicated horizontally and vertically depending on necessity. In other words, a search for the architecture of Metabolism is suggested.

Metabolism was a Japanese architectural movement founded in 1960 by Kenzo Tange with members including Kisho Kurokawa, Kiyonori Kikutake, and Fumihiko Maki. Their vision of a city of the future inhabited by a mass society was characterized by large scale, flexible and extensible structures that could support an organic growth process. In their view the traditional laws of form and function were obsolete. A Metabolist building should be capable of supporting a variety of functions that would change with time and needs. The Metabolists believed that the laws of space and functional transformation held the future for society and culture. The group's work is often called technocratic and their designs are described as avant-garde with a rhetorical character. The work of the Metabolists is often comparable to the unbuilt designs of Archigram. The steel pipe units played a major role in this pavilion and its realisation of the vision of Metabolism.

Kisho Kurokawa is the architect most associated with Metabolism. He designed the prototype for a new type of modular living structure. Although it was dismantled after 6 months’ service, it became the inspiration for his Nakagin Capsule Tower, another plug-in housing structure, built a couple of years later in Tokyo and still standing today. Even though the total floor area is only 1,237.6m² this structure is an innovative starting point for thinking about demountable units. The Theme Pavilion and

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184Kurokawa, K. (1934-2007) was a Japanese architect and philosopher, and founding person of the Metabolism Movement. From 1960, he advocated for a paradigm shift from the Age of Machine Principle to the Age of Life Principle. The concepts he advocated, comprising Symbiosis, Metabolism, Information, Recycling, Ecology, Intermediate Space, and Fractal Geometry are all important issues that relate to the Life Principle.
Toshiba IHI Pavilion at the Expo in Osaka were designed by him as well, but neither building had demountable elements.

A Russian specialist in Japanese research, Galina Navlitskaya,\textsuperscript{185} has commented that Osaka Expo ‘70 on the one hand set the future prospects of urban development in Japan and the wider world and on the other hand, interpreted the relationship between human beings and science and technology, moving this from the shelter of the laboratory into reality.\textsuperscript{186}

\section*{4-4-2 Expo 2005 in Aichi: focus on environment and sustainability}

The next World Expo held in Japan with the theme "Nature's Wisdom" was World Expo 2005 in Nagoya, Aichi. Its purpose was to explore the potential harmony between mankind and nature and the potential for development to be sustainable. The planning of the venues and construction of the halls of the Expo widely reflects the concept of sustainable development from different angles.

\subsection*{1) Selection process of the venues}

Expo ’70 Osaka was remarkably successful. Osaka is the most important city in Kansai and the three economic foci of Central, Capital, and Kansai are generally known as the representatives of Japan’s main stream economy. The rapid development of Kansai in the decade after the expo, also helped to promote the growth of Japan’s economy. Japanese GDP in 1970 was the pinnacle of this growth at 21.2\%.\textsuperscript{187} The magnificence the Osaka World Expo probably contributed to this economic miracle.

\textit{In the 1960s, Japan's dependence on energy from foreign sources reached 80.9 percent of consumption. About 70 percent of these were in the Middle East, particularly in Saudi Arabia, Iraq, Iran, and the Gulf states. The relatively cheap oil in the 1950s and 1960s was an important component of what would later be called the Japanese economic miracle. Japanese industry became more energy intensive than in other countries because of the growing dependence of its heavy industry, its steel and shipbuilding, and its chemical and petrochemical industry on oil; by the beginning of the 1970s Japan's dependence on imported energy reached 90 percent.}\textsuperscript{188}

With the outbreak of the first energy crisis in 1973 after the Osaka Expo, people gradually began to realize that the higher the rate of growth in the economy, the more prominent the environmental

\begin{footnotesize}
\textsuperscript{185}Navlitskaya, G. B., was a professor at the Moscow State University's Institute of Asia and Africa
\textsuperscript{186}http://www.expo2010.cn/a/20080529/017532.htm
\textsuperscript{187}Francks, P., Boestel, J., Kim, C. H., Agriculture and Economic Development in East Asia: From Growth to Protectionism in Japan, Korea, and Taiwan; London and New York: Routledge, 1999
\textsuperscript{188}Cohen, Y., Japanese-Israeli Relations, The United States, And Oil, Jewish Political Studies Review 17:1-2 (Spring 2005)
\end{footnotesize}
pollution question became. These problems led people to question the pattern of success of Expo’70. Thirty five years later, the general public has some consciousness of the severe damage to the environment caused by immoderate construction and development. As a result, both environmental protection and sustainable development became the main issues for venue planning and building construction at Expo ‘05 Aichi.

In 1996, Aichi successfully bid to host the World Expo 2005. The Aichi Expo was first planned in accordance with established practice to host an exposition promoting human progress and advocating “the investment development.” A hilly area of about 2000 hectares called Marine Forest was selected as the main venue for the Expo. The area is located 20 km east of Nagoya. At its centre is a lake, and the area contains more than 3000 kinds of wild animals and plants. This area is the habitat of local goshawks and other valuable flora and fauna. However, this project encountered intense opposition from environmental protection groups and the BIE. Finally the organizers decided to shift the main venue in a move not to damage the environment. To this end, the main venue switched to the Aichi Young People’s Park, and only 15 hectares of Marine Forest were retained as a sub-venue to highlight environmental protection.

At the same time as this initial planning occurred the development of information technology meant the platform for international exchange had become increasingly broad and as a result the international exhibition industry was itself facing unprecedented challenges. Germany's Hannover World Expo of 2000 had not achieved the anticipated success. Numbers admitted had been lower than anticipated and there had been a loss. The plan for the Aichi World Expo was adjusted because of these issues. The original venue area of 540 hectares was scaled down to 250 hectares, and then adjusted to 173 hectares. The goal for admissions was also scaled down from the original 25 million to less than 15 million. This meant that the planning Expo 2005 could be viewed as a balance of the political, economic and cultural influences at that time.

In the final executive plan, Aichi Expo made a special effort to adopt environmental protection measures such as using renewable energy sources like solar power generation and waste power generation. The changing of the main venue of the Aichi expo clearly verified that the idea of sustainable development had taken the place of only pursuing the development of science, technology
and economy. In other words, the Japanese public put more emphasis on environmental protection and saving natural resources than pursuing economic interest.

2) Design and construction of Expo 2005 Aichi

In the 20th century, human beings were the cause of the excessive use of resources and environmental destruction. Therefore the first fair in the 21st century to no longer stress development, took “Nature’s Wisdom” as the theme of the Expo and emphasized how, in the new century, people and nature could coexist, and create a sustainable peace. Unlike the Osaka Expo with its 1970’s emphasis on world economic growth, the Aichi world expo focused on new technology and displays that emphasised environmental protection and a new mode of civilization.

Another worthwhile aspect of this expo is the design of the exhibition facilities. Most of the buildings in the Osaka Expo pursued conspicuousness and luxury, and were bombastic structures, rather like acrobatic performances. However, the advocated concepts in the Aichi Expo were related to sustainable development, such as less land occupancy, economy in use of resources, and recycling potential. Expo 2005 Aichi used the “module” method and provided standardized modules, or lots of land and buildings to participating countries and international organizations for their exhibits. The size of one module was 18m x 18m x 9m (L x W x H). These modules could be recycled or reused, and formed a real challenge for the architects who participated in pavilion design because of the severe limitations of the module size. Thus many designs put more attention on energy saving and reuse. A lot of pavilions were made from materials which could be recycled, reused or that could spontaneously decompose after the event.

From the viewpoint of Expo history, the design of pavilions at Expos generally emphasizes novelty and experimentation. Many buildings which were born at Expos have been handed down as masterpieces in building history; some of them are even viewed as milestones of modern architecture, such as Le Corbusier’s Pavilion of the New Spirit at the Paris Exposition of 1925; Mies van der Rohe’s German Pavilion at the Barcelona Expo 1929, and Alvar Alto’s Finnish Pavilions for both the 1937 Paris Exposition and the 1939 New York Exposition. In contrast, at Expo Aichi the organizers paid more attention to process, such as layout, construction and reuse after dismantling, than to

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189 Pavilions were categorized according to the number of modules they consisted of. Category A: 4 modules or more; Category B: 1.5 to 3 modules; Category C: 1 module or less. Meanwhile, Category D is for joint pavilions.
building images and facades. Design innovation based on the concept of sustainable development was the principle of all design works for the Expo.

3) The 3R measures
The theme “Nature’s Wisdom” demonstrated that the general aim for Expo Aichi was to open up solutions for sustainable development and mankind's harmonious cohabitation with nature. Constructing a “Circular Society” was set as one of the sub themes of the Aichi Expo. It is also one of the solutions put in place for environmental protection. As soon as the construction work started on building the venues, the “3R (Reduce, Reuse and Recycle) Measures” were established as the guiding rule for the work.

The set-up of the venues and pavilion designs at the Expo were supposed to reduce impact on the environment and to have smaller ecological footprints. This is true in the strict sense of the word “footprint” when considering the construction of the elevated Global Loop, which was erected to minimize visitor impact on the venues of Nagakute. The Nagakute Area was formerly Aichi Youth Park, an undulating area with a maximum topographical variation of almost 40 metres, dotted with sports facilities such as baseball grounds, tennis courts and a skating rink. To facilitate visitor movement through this environment, the Global Loop was conceived by architects KikutakeKiyonori and Harada Shizuo. This huge elevated circular walkway is designed to require minimal modification to the area’s topography and was erected so as to detour construction around existing natural ponds and precious habitats of fauna and flora. The walkway level is a barrier-free structure, with an almost completely horizontal surface, for the comfort of all visitors. Its maximum incline is 3 degrees, with inclined sections punctuated by horizontal intervals to prevent excessive wheelchair speed. The walkway surface is made of wood instead of asphalt. The walkway’s standard width of 21 metres is almost evenly divided into three sections: a middle section made of a half and half mixture of waste wood and waste plastic, and two side sections made of Brazilian eucalyptus, a product of planned forestation. Japanese cedar collected from forest thinning\(^{190}\) in Aichi Prefecture is used for part of the walkway. The central section material is reinforced with plastic, since that section served as a route for trams and emergency vehicles.

\(^{190}\)Forest thinning involves felling some trees in a forest to enhance the growth of remaining trees and thus the health of the forest as a whole. Without thinning, forest trees remain in a high density that means they will be weakly rooted and vulnerable to heavy precipitation, which can uproot some trees, leading to mudslides. These sometimes wash trees into rivers and carry them downstream, causing considerable damage to riverside properties.
The Global Loop leads visitors to six Global Commons and Corporate Pavilions. In other words, visitors can take a “trip around the world” by promenading on the Global Loop. At 2.6 km long and 21 m wide, the Global Loop is arranged in a figure-8 shape and soars to 14 metres above the ground at its highest points. In short, it is actually a viaduct for people and service vehicles through an undulating park area. It offered a panoramic view of the park and Nagakute area which gave a unique image completely different from the view at ground level.

The whole Global Loop was 2.6 km. Some parts directly connected with the ground but about 2 km of the walkway appears like a floating bridge. The longest supporting structural element was 14 metres and their average length was 7.5 metres. For easy restoration of these parts of the site after the Expo, a helicoid and press-in type of steel pipe pile was adopted for the foundation. The number of pile foundations was reduced as the 4 to 12 supporting pipes were radially fanned out from the foundation underground. Because this structure of iron “fan pipes” was in a tilted state, it had a higher bearing capacity to horizontal load (as imposed by wind or earthquake) and vertical load (as imposed by gravity). More importantly the foundations could be easily pulled out if required once the expo ended. The whole process of the Global Loop has a strict sense of control, and embodies the concept of the 3Rs.

Rather than leveling vast tracts of land to build sophisticated structures and displaying state-of-the-art technology, Expo 2005 Aichi, differs from most previous Expositions, by adopting a concept that is radically different from the conventional development-oriented approach. Using the Global Loop the Expo 2005 Aichi sites preserved their natural conditions to the maximum possible. This is the first such attempt in Expo history.

4) Aichi Expo: a new chapter in green building

The history of reusing an exhibition pavilion can be dated back to Expo 2000 in Hanover, where Peter Zumthor’s Swiss Pavilion was a forerunner of the work at Aichi. His design originated in a common, everyday image, being the simple stacking of wooden boards of larch and Douglas fir from Swiss forests, in an ordinary carpenter’s stockpile. The 2800 cubic metres of the small building were composed of 45,000 boards of unseasoned wood. This amounted to 144 km of lumber with a cross-section of 20 x 10 cm, assembled without glue, bolts or nails. The 9 m high walls divided up the internal space according to a complex maze-like logic, while walls were made of larch beams rested
on vertical beams of Douglas fir. They were held in place by being braced with steel cables, with each beam being pressed down on to the one below. This Swiss Sound Box was an elegant minimalist design, following the nature of wood as a changeable, living material. After the closure of the Expo, the building was dismantled and the beams sold as seasoned timber for reuse at a regional exhibition in Switzerland.

Another stunningly modern, environmentally friendly exhibition hall in Hannover was Hall 26,191 at the Hannover Trade Fair. Although it was not originally built for an Expo it was part of the Hannover Expo 2000. The hall’s design took the theme of sustainability as seriously as the Swiss Pavilion but was larger in size. It used indirect sun light, natural ventilation and cooling, and many other state-of-the art energy-saving features. For fast setting up, a suspended structure was adopted, with the roof sagging between tall trestle masts which were prefabricated, and then transported to the site to be quickly pinned to their footings and hoisted into position.

Unlike former expositions that have always left some tangible legacy, Aichi Expo had a strict sense of control from the first step of planning to the dismantling of all expo facilities and rehabilitation of the venues. In order not to change a venue’s natural settings and disturb the forests, it was intended that the buildings should be built quietly, and then should be removed quietly. From the view of sustainable development, Aichi Expo 2005 did more and better works than Expo 2000 in Hannover. In other words, if sustainable development is likened to a musical, at Hannover Expo there were only a couple of solo performances, but five years later at Aichi Expo people could enjoy colourful music at all venues.

Reviewing the history of Expositions, with their pavilions and venues reveals they have not only been the means of showcasing new architectural ideas and thoughts, but also the pathway to modern planning and construction. The overall aim of 20th century Expos has been the pure pursuit of technological development and economic progress. However, when the 21st century arrived with its global problems related to the environment, these concepts have inevitably given way to the philosophy of sustainable development.

191 Hall 26 for the Deutsche Messe AG (DMAG), was designed by Herzog + Partners, and built in 1995-1996.
In Japan there were two reasons for these changes. First of all, Japan is a small country with a large population. Although Japan has embraced industrialization, its land and natural resources are very limited. So, both governmental and public awareness of environmental protection in Japan is stronger than in some other countries. Secondly, after the issuing of Agenda 21 by the UN in 1992, Expos, like those of Lisbon 1998, Hannover 2000 and Aichi 2005, all offered discussions and explorations of “sustainable development” from various perspectives. On June 8, 1994, the 115th Session of the General Assembly of the International Exhibitions Bureau adopted the resolution that future exhibitions would have “a commitment to the supreme importance for Humanity of due respect for Nature and the environment.” This decided the future direction of international exhibitions of the 21st century as a forum for resolving global issues. The BIE’s decision also played the role of reinforcing the message. Thus Aichi 2005 continued to give more attention to sustainable development than did Hannover 2000, as each Expo built on the experience of the last. The realization of the 3Rs measures marks a step forward for the Aichi Expo. However, compared with pavilions created for earlier expos, the organizers of Aichi gave much more attention to the planning, construction, demolition, reuse and design innovation under the concept of sustainable development. As the Japanese architectural commentator Taro Igarashi pointed out, if the dismantled materials from the Expo venues can be reused somewhere else in the manner of the way that the shrine of Ise Jingu is regularly rebuilt, this will mean the Aichi Expo would have been a tremendous success. Ise Jingu is reconstructed every 20 years according to the prototype as a part of the Shinto belief in the death and renewal of nature. This reconstruction both maintains continuity and is also a way of passing architectural techniques and traditional crafts from one generation to the next. The replaced building materials after reconstruction will be used in the god’s palace, or other palaces, or will be given to regional shrines in Japan for reuse. This is the proof of the wisdom of ancient Japan for preservation, and for use of the 3Rs measures. However, today’s exhibition hall is much more complicated than a shrine built a thousand years ago. The problems that today’s society and people are facing cannot necessarily be compared with those of before.

Unlike the architecture of the past, contemporary architecture must be changeable, moveable and capable of meeting the changing requirements of the contemporary age. In order to reflect

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192 Bureau International des Expositions: shortened to BIE

193 Ise Jingu, or simply "Jingu", is the only one of Japan's 100,000 shrines dedicated to the Sun Goddess and Supreme Shinto Deity, Amaterasu Omikami, with a 2,000 year history. It is located in the city of Ise, in the Mie prefecture, Japan. The shrine buildings at Naikū and Gekū, as well as the Uji Bridge, are rebuilt every 20 years. The last reconstruction was in 1993 (61st time) for a total cost of no less than ¥5 billion.
dynamic reality, what is needed is not a fixed, static function, but rather one which is capable of undergoing metabolic changes.\textsuperscript{194}

It is no exaggeration to say that Aichi Expo is a world exposition linking preceding Expos with those to follow. It offers a precious opportunity to learn the concept of sustainable development and the design means to create green buildings. Meanwhile Aichi Expo also offers a successful model for future architectural design and mega-events planning.

\textbf{4-5 Making an Expo into an Endless World’s Fair}

Because they are built for international celebration and boosting trade, Expos are unlike Olympic Games events, which have specific building and facilities requirements. Expos are more flexible and can leave behind a host of developments that can be an aid to urbanization. The physical improvements and additions to a locality's infrastructure have prompted many cities to bid to host world's fairs, even in the face of the huge financial deficits left behind for many former hosts. Parks, museums, science complexes, urban corridors, and transportation facilities are not only a tremendous boost to the enjoyment of the local people, but are also an indispensable resource in the urban context of a host city. Toronto was unusually enthusiastic about hosting an Expo partially because there is brownfield land right on the waterfront of Toronto’s CBD. Certainly, Toronto intended to use Expo 2015 as a vehicle for boosting its Port Lands development. Of course turning a short term fairground into good urban development even with a successful Expo bid is not enough, and formidable local endeavour is still required. The history of the redevelopments of the False Creek site, Balboa Park and Flushing Meadows Corona Park has shown this.

Expo activities are ephemeral, so the halls on the site of an exhibition are not permanent. It is inappropriate from certain angles that the large-scale display facilities required for a short period of time could be considered for permanent or long-standing uses, particularly in cities. Such large buildings can be inappropriate for a human scale urban fabric, although not necessarily when it comes to entertainment activities. Under current circumstances, if the forms and structures of expo buildings are not going to change in an evolutional manner through the need for reuse or redevelopment, the entertainment attributes of the buildings that remain could be one of the best choices for a sustainable solution.

\textsuperscript{194}Curtis, W.R. (1996), \textit{Modern architecture since 1900}. London: Phaidon
The major concern for urban planners and architects is how to maintain or strengthen the attraction of the fairground as a part of an urban centre for the public. Turning fairgrounds into urban parks is only one kind of solution. However, as long as the continuing use of the venue directly relates to what residents and communities need in their daily life, the fairground has the possibility of becoming a constituent of an urban system, thus making the Expo an endless world’s fair.
CHAPTER 5 WHAT PEOPLE THINK ABOUT EXHIBITION BUILDINGS

5-1 Two Early Prefabricated Exhibition Buildings in London

Each year the Crystal Palace and Joseph Paxton are essential knowledge for every examinee who is taking the Entrance Examination for Postgraduate Study in architecture at Chinese universities. When talking about the earliest prefabricated building, some people may think of Nonesuch House which was built on London Bridge in 1577, but in terms of scale in British architectural history the Crystal Palace is the building that fully deserves the title. The Crystal Palace used 4,500 tons of iron, 60,000 cubic feet of timber and needed over 293,000 panes of glass, and it took 2,000 men just eight months to build its 770,000 sq ft. of floor area. Such a large scale temporary building within so short a time frame would even now be a real challenge for any architect.

It is no coincidence that the history of the Crystal Palace stands alongside that of another prefabricated building—the Museums of South Kensington (known as the 'Brompton Boilers') which were erected in the middle of the 19th century. As a major turning point in world civilization, the Industrial Revolution in Great Britain that occurred in the late 18th century made a fundamental contribution to further technological, socioeconomic, and cultural progress. The influences of the Industrial Revolution, on almost every aspect of daily life and human society, are self-evident. With displays of the emerging industries in the power and mechanisms fields and the rise of new materials and technology, the Crystal Palace, the first of this kind of exhibition hall, was a building that was really true to its time.

Fig.5-1(left), Crystal Palace from the northeast from Dickinson's Comprehensive Pictures of the Great Exhibition of 1851. Fig.5-2 (right), constructing the Brompton Boilers, April 7th 1856. Photograph by B.L. Spackman.

195 BBC, OldLondonBridge, http://www.bbc.co.uk/london/content/image_galleries/old_london_bridge_gallery.shtml?10
196 Peter Buckley, Will the Crystal Palace rise again? May 5, 2011 in Articles of Interest to History, http://www.thebookblog.co.uk/2011/05/will-crystal-palace-rise-again/
Joseph Paxton, the designer of the Crystal Palace, is usually considered to be an engineer. In fact, he had been the head gardener at Chatsworth, in Derbyshire. Becoming a friend of its owner, the Duke of Devonshire, Paxton had the chance to experiment with glass and iron in the creation of large greenhouses, such as the Victoria Regia House and the Great Conservatory. From these buildings Paxton accumulated knowledge about the strength and durability of these materials and he employed his experience and knowledge in the plans for the Great Exhibition building with astounding results.

Although 150 years have now passed, Paxton, though never formally educated, had shrewd ideas about a modular construction system. These have since inspired many architects from one generation to the next. The Crystal Palace still has an influence on exhibition design, and after almost 160 years a replica of the original Crystal Palace is being worked on by architects and developers. The plans for the replica were approved after a Public Inquiry in December 2010.197 Certainly people have never forgotten this building even though it was destroyed by fire in 1936, and has also been cynically described as an “oversized greenhouse,” “glass monster,” and “a cucumber frame.”198

![Fig.5-3 left, Exterior of the Brompton Boilers, by Lanchenick, c.1860. The entrance sign reads 'Museum of Patents, Entrance Free Daily'. Fig.5-4 right, exterior of the Children’s Museum of South Kensington in Oct. 2010.](image)

Compared with the Crystal Palace, the Museums of South Kensington gained much less attention and are rarely mentioned in architectural textbooks. Like the Crystal Palace, the 'Brompton Boilers' have also been subject to criticism. The 'Brompton Boilers' were built by the firm Charles Young and Company, which specialized in 'iron structures for Home and Abroad', including hospitals and barracks. Although favored by public officials for its 'simplicity and cheapness', the structure was

197 Ibid.
condemned in the press as ‘vilely disfiguring.’ From Fig. 5-2 which is an image made on site soon after completion, the construction technology was comparatively advanced and the interior structure was completely exposed. A hoist had been adapted to erect and assemble the complete frames. This reduced the number of workers on the site, as some structural components were prefabricated at iron yards prior to being transferred to site.

After a time in South Kensington, the Brompton Boilers (Fig. 5-3) were dismantled and taken across London to Bethnal Green where they were re-erected and eventually became the official Museum of Childhood. The Museum secured funding from the Heritage Lottery Fund for a major redevelopment to improve facilities and displays in 2003. It later reopened following a £4.7m refurbishment, which is sufficient money to build a new museum. The question has to be asked whether this is money well spent since the exposed prefabricated structure makes the building very noisy internally, especially when full of excited children. The Museum’s new entrance looks unhappily placed in front of the old building (Fig. 5-4). The question asked in this thesis is whether such prefabricated buildings can be better designed so that they are always fit for their purpose.

As part of finding an answer to this question a survey was conducted to see what people thought about exhibition buildings. The background and design of the survey are discussed together with the results in the following sections.

5-2 The Background of the Survey

Nowadays, a large number of pavilions and arenas are being built for a wide variety of major events such as the World’s Fair, Olympic Games and so on. These events last for a few days to a couple of months. Unfortunately, when the events are over, most of the halls will become a burden on the urban environment in terms of need for their redesign, maintenance, or disposal. Such large scale construction activities use a large portion of natural resources, including the most precious of all; land. Most are neither recyclable nor renewable. Natural resources cannot be used in this way without restraint. There is a need to find an optimum way or system to balance the situation.

This project is based on finding design solutions so that, through innovative design, formerly fixed exhibition buildings can be replaced by more flexible designed parts and units. These can be used repeatedly and combined in other locations in different shapes for different purposes. This type of
exhibition building will make a significant impact on the environment and architecture by reducing the event’s permanent footprint. The hypothesis is that this will have less impact on the environment than the current method of procuring exhibition buildings.

5-3 The Purpose of the Survey

Using demountable architecture for events buildings will, it is expected, result in a move to a more efficient and environmentally friendly world. More importantly this type of exhibition building should have a significantly reduced impact on the environment by reducing the event’s permanent footprint, together with material and energy waste, and bringing into focus viable recyclables.

The general aim of the survey is to gather information which will help to give an understanding of exhibition buildings from the viewpoint of people who are involved or concerned with the exhibition industry or a sustainable future. From this, the research will then be in a better position to discover whether demountable exhibition buildings would be acceptable in current society.

The specific aims of the survey are set out below.

1) To discover whether demountable exhibition buildings would be acceptable in current society.
2) Modern exhibitions are more sophisticated and complex, so the second aim is to discover whether a demountable exhibition building can accommodate today’s exhibition requirements.
3) The technology used has a large influence on this special type of design, so a further aim is to reveal whether the inherent architectural aesthetics are acceptable.
4) Holding a World’s Fair or an international conference is considered to be a major factor in establishing the worth and position of a country internationally. It is taken for granted that waste is created for such major events, so the survey will investigate whether this is a tenable position in a sustainable future.

The survey is seeking the opinions of those involved in exhibition design and those interested in exhibition buildings or the use of demountable exhibition buildings. Participation in the survey was voluntary and participants were free to give their opinions in answering all questions. All the information has been kept strictly confidential within the research process. The questionnaire was anonymous and each response was confidential.
5-4 The Participants in the Survey

The original intention was to link the survey to a photographic exhibition on exhibition buildings. To this end an exhibition of photographs based on a narrative entitled *Towards Green Exhibition Building Design: a comparison between North America and Tibet*, was carefully organized by the author. The exhibition represented the author’s raw records from investigative trips undertaken during the course of this thesis research to seventeen Expo and Olympics sites in North American cities and the Northern Prairie in Tibet’s highland. They therefore formed the prelude to the survey to discover whether demountable exhibition buildings would be acceptable to both professionals involved in the exhibition industries and the general public. The main purpose of the exhibition was to invite more public interest and input, thus ensuring sustainable architecture can be established in the genre of exhibition buildings.

There were two ways of participating in this original survey:

- **Type A**: Completion of an anonymous questionnaire which was to be handed to participants. The participants’ questionnaires were strictly anonymous and Chinese questionnaires were available on request.

- **Type B**: With the agreement of the participant and through signing the Consent Form participants also engaged in a structured interview which was face-to-face or by email/mail with pre-designed questions. Chinese versions were available on request.

The author identified most potential participants from the audience who attended the photographic exhibition. At the same time some questionnaires were sent to target professionals. Anonymous questionnaires were also available at the photographic exhibition for people to pick up and fill out if they wished. Those filling out the anonymous questionnaires are Type A participants. It was voluntary whether or not Type A participants left their names and contacts, in case further communication was needed.

At the same time, the author made an initial approach to professionals (for example architects, engineers and contractors involved in exhibition building design) by sending them the questions as a hyperlink in a message of invitation for them to participate in the survey. These were the basic Type B participants. Where the professionals above were agreeable an interview was conducted. These were
the special Type B participants. The original intention was that at least 30 professionals were to be Type B participants.

5-5 The Survey Procedures

The initial methods used for obtaining information were written and e-mailed questionnaires for selected participants in the first stage. Mainly the research procedures were to take place at the sites of the photographic exhibitions which were to be held in several cities related to Expos, such as Hong Kong and Shanghai.

The time needed for participants to take part in the research was about 10-20 minutes for the questionnaires and 30 minutes for the structured interview. The possible benefits to research participants of taking part in the survey were that it would potentially help them think about the problems and future of exhibition buildings.

5-5-1 The first phase of the survey

Due to the shortage of funding and time, and although many potential hosts had indicated a willingness to hold the exhibition, such as the city of Edmonton, Toronto in its City Hall, the City of Sydney, the 2010 Interdisciplinary Graduate Conference of the University of Cambridge, the University of Liverpool and the Chinese University of Hong Kong, finally the exhibition was successfully held in just two places. These were the College of Fine Arts of the University of Shanghai and the School of Architecture and Planning of the University of Auckland. However, this did give feedback from people in two very different locations.

The time period from the day of ethics approval by the University of Auckland Human Participants Ethics Committee on April 9, 2009 to the end of 2010 was defined as the first phase of this survey. This phase was characterized by author’s direct contact by hand, mail or email with potential participants to complete the questionnaire, some of which came through holding the exhibitions. There were a total 39 structured questionnaires sent via mail or email to target professionals such as architects, engineers and contractors who had been involved in exhibition building design internationally. However, from these only three replies were received. Fortunately, these three, who have agreed to be named in this thesis, offered very valuable opinions. They were Prof. G. Goetz...
Schierle, Prof. Dai, Ruitong and Prof. Jiang, Senrong. Because of the low response personal contact was made with some young architects and architectural students, who also agreed to be named in this thesis. These were Mr. Su, Xinbao, Mr. Gao, Gong, Mr. Zou, Xun, Mrs. Hu, Jiani and the architectural students were represented by Mr. Zheng, Rui and Mr. Yang, Yinghao from the College of Fine Arts of the University of Shanghai. As they all agree to the release of their names, comments will be listed under their true names in the following discussion of the survey results from the first phase. This gave a total of 9 participants. The questionnaires to participants in the first phase were in both English and Chinese. If the answers were in Chinese, they have been translated into English for reporting in the thesis.

5-5-2 The second phase of the survey on line

Because of the problems of linking the survey to the photographic exhibition and the low number of participants in the survey up to that time, from November 2010, the survey changed its focus to China. This was appropriate as China had just seen the closure of the biggest Expo in history. The platform of the survey was also switched to being on line via zhidao.baidu.com, which is the leading search engine in China with about 300 million visitors. It provided a useful ask-and-answer environment for both kinds of participants and a reward system for some popular answers. Judging from the number of answers this second phase was much more successful in terms of participant numbers. The questionnaire was published at zhidao.baidu.com 19 times from November 8, 2010 to June 9, 2011.

To identify some of the opinions from the online survey shown below some basic information on the participants as registered on the relevant web sites are given key letters as below.

G for great128, male, Education: University; Current Occupation: Advertising / Marketing / PR.

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199 Professor Schierle is a Fellow of the American Institute of Architects, recipient of the ACSA Creative Achievement Award, founding director of the University of Southern California (USC)’s Master of Building Science Program, and a professional architect. He taught at UC Berkeley and Stanford University before coming to USC, where he teaches structures and design.

200 Prof. Dai, Ruitong (戴瑞同教授) is a Fellow of the Institution of Civil Engineers (ICE) and the member of the Chartered Institute of Building (CIOB), chief editor of the Drawings Set for Design of Residential Building I & II (住宅设计图集 1, 2) published by China Building Industry Press in 2001 and 2007 in Beijing. He is also a chief Chinese translator of Seismic Design of Reinforced Concrete and Masonry Buildings by T. Paulay and M.J.N. Priestley which was published by China Building Industry Press in 2011.

201 Prof. Jiang, Senrong (蒋森荣教授) taught structures at Tongji University and was the editor of some popular Chinese text books such as the Calculation of Reinforced Concrete Structures by Shanghai Science and Technology Press in 1978 (钢筋混凝土结构计算, 上海科学技术出版社 1978), Introduction of Masonry Structures by Shanghai Science and Technology Press in 1960 (砖石结构入门, 上海科学技术出版社 1960) and both were reprinted several times in China.


203 http://passport.baidu.com/?business&aid=6&un=great128#0
5-6 Selected Answers with Some Statistics

In this section the question is first posed and then the answers of various respondents given afterwards. The answers are given in English although most of them were entered in Chinese. In terms of the survey as a whole, a total of 52 usable responses were received out of an eligible sample of 78, representing a 63.2% response rate.

5-6-1 What is your opinion of the Crystal Palace as an exhibition building for today?

Prof. Schierle: The Crystal Palace was an innovation for its time, featuring prefabrication and energy saving natural daylight but its very large footprint required much land.

Prof. Dai: It is reasonable to utilize fabricated construction as an exhibition venue, which is in line with the sustainable development concept. From this point of view, the Crystal Palace could stand even today as a large exhibition venue. But the problem is the technology level in 1851 was not as good as today’s, so it could be a more beautiful and more advanced exhibition hall definitely if it were built today.

Prof. Jiang: I thought it undesirable to use glass as the main material for facades, because most pavilions have adapted use of multimedia devices for showing or displaying their exhibits which have to avoid the interface with natural light.

G: This is not a professional exhibition venue, and you may come across many problems related with lack of hardware for organization of the venue (e.g. display and control of people flow), if hosting a large exhibition event there today.

C: It is a kind of restoration, but I am not sure if it could accommodate so many visitors today.
H: Impossible, although the Crystal Palace was also a controversial construction in its time.
X: The Crystal Palace could be an example of breakthrough architecture, and its new conception reflects its designer’s thoughts, meanwhile, as a venue its cross shape with a strong spatial sense would still attract a lot of tourists today.
Z: It is okay and similar to the Beijing Imperial Palace; it is cultural heritage.

For this question (n=52), the answers are summarized as follows (numbers in brackets are the total number of participants for this question):
The Crystal Palace is a good exhibition venue 28.9% (15)
The Crystal Palace is a poor exhibition venue 26.9% (14)
I feel neutral about the Crystal Palace 19.2% (10)
Don’t know 25% (13)

5-6-2 Do you think that major exhibitions are a waste of land and resources?

Prof. Schierle: Good exhibitions are needed to inform about advances in technology, etc. but they should be adaptable for future needs.
Prof. Dai: I don’t think so, the exhibition industry is a major component of modern service industry, and has an immeasurable effect in economic development.
Prof. Jiang: No.

G: Of course not, a good exhibition could not only please audiences but the more important thing is to build a platform for industry demand and supply need, and stimulate the urban economy.
C: Not necessarily, it is good if it is three-dimensional.
H: In some cases, waste also can be good, and economic development is a kind of waste (build and destroy and rebuild). However, most pavilions in an Expo are removable and the remaining ones have their own uses, so this should not be considered as waste.
X: This question cannot be thought about in an absolute way. I think it is necessary to keep some pavilions with strong time, historic and humanistic significance, and so on; contrarily, destroying other buildings should be considered as wasting resources.
Z: No, because recently the city has developed a need for some kind of public exhibition space for cultural activities, and these exhibitions are the carriers of city culture.
For this question (n=50), the answers are summarized as follows:
Exhibitions are not waste of land and resources 54% (27),
Exhibitions are waste of land and resources 12% (6),
Neutral 18% (9)
Don’t know 16% (8)

5-6-3 What do you think is the best architectural form for an exhibition building?
Prof. Schierle: A round form would minimize the envelope for a given floor area, but require much land. The optimal form would be adaptable to available site configurations.
Prof. Dai: It is better to use irremovably assembled model architecture; and for permanent venues, either a fabricated or cast structure is accepted.
Prof. Jiang: It is best to combine the function of exhibition and reusability of space, to have ephemeral pavilions which have to consider being dismountable and reusable at least for the major components.

G: Personally, I think the first job is to solve the service needs of exhibitors and visitors, as well as the management environment for organizers; as architectural form should be a combination of the exhibition’s history and culture and historical background.
C: Always designed as a twisting spiral surrounded by exhibits and with a spacious corridor and without a stage, so people can go straight down by elevator when they reach the top floor.
H: Recycling, energy saving and innovative ideas
X: First, blend with surrounding environment; could fully reflect the sense of time; should not be too Pharisaistic; and also it should be full of cultural atmosphere and consider people’s relationships and space exchange elements and so on.
Z: It could be different forms, but most important is to ensure the “exhibition space” under various forms of skin, which must be an open, fluent space and have room.

For this question, participants were asked to opt for a number of suggested forms for exhibition buildings (n=50):
Demountable 18.0% (9),
Adaptable 10.0% (5)
Reusable 16.0% (8),
Don’t know 56.0% (28)
5-6-4 What do you think of the idea of housing exhibitions in demountable and reusable buildings?

Prof. Schierle: Adaptable/reusable exhibition halls would be very desirable.

Prof. Dai: No problem.

Prof. Jiang: A very good idea.

G: Exhibition space belongs to a hardware environment, which is one of the important factors to make an exhibition successful. In the case of being without a professional venue or where the space is not big enough, display can be inside tents outdoors. Its only advantage is that this could lower the cost compared with a professional venue; and some disadvantages include issues in exhibition on-site management and exhibition grade; meanwhile, booth design is limited and there are related outdoor security risks etc.

C: Could save resources, good idea.

H: Good idea, protect environment, but not at the expense of safety.

X: Good, it is the best way to express space reuse and also with meaning and makes full use of land resources.

J: The best venues worldwide are all irremovable, unless needed for a touring exhibition.

Z: It could be good. Take the buildings of Shanghai Expo as an example, most of them are beautiful but all have to be removed after this event; in this case, a removable structure is beneficial; but if the building could be kept after its first use as a permanent building its exhibition theme could be changeable.

For this question (n=46) answers are as follows:

For using demountable and reusable buildings for exhibitions 63% (29),
Against using demountable and reusable buildings for exhibitions 4.3% (2),
Neutral 8.7% (4)
Don’t know 23% (11)

5-6-5 How could exhibition buildings be made more flexible?

Prof. Schierle: Through prefab modules that can be configured for new needs.

Prof. Dai: Using large column grid and large space for the construction of pavilions.

Prof. Jiang: The flexibility will demand that most of the main components can have the possibility for different kinds of assembling and extending.
C: Anytime and anywhere are the general characteristics of a flexible exhibition. In order to achieve this ideal situation, there is a requirement for exhibition demolition. It is possible to achieve flexibility by using smart block-model components and appropriate building materials. There is also the need to pursue “delicacy” in considering colour and shape, and the shapes of the jigsaw—for example, white, blue and some other not so strong colours could be reused many times. Juggling a kind of basic component but with different shapes that could play different roles in different positions would be good. Putting it simply, this is like children’s building blocks, a triangle, could be used as a roof and as well as a post. Moreover, colour is the most effective method to prevent eye fatigue. Different regions require different colours. Plus, rotundity is the most difficult shape to operate but is also is the easiest to be changed; different ring stacking makes different styles.

H: Take advantage of steel structure, cable, and membrane, etc. in favour of bigger space structure.

X: Should be designed into reused construction.

J: Just like fast building blocks such as the Great Pavilion.

Z: Building internal partition walls and construction envelope should be completely separated; it could be a large space and could also be divided into several small rooms.

The top three choices in terms of making exhibition buildings more flexible were demountable, prefabricated module, and being reusable.

5-6-6 Is there a feasible solution to the cost, logistics of transport and storage of elements for demountable structures?

Prof. Schierle: Design of modules/elements small enough to fit in containers.

Prof. Dai: D: The key is that each removable cell should be divided in a reasonable way, not only to make sure each cell is under reasonable stress and transferring force directly but also to connect them easily.

Prof. Jiang: According to the requirements of logistics and storage, the solution should include use of local-made standard profiles, even from domestic wastes, plus a heterogenic skin.

G: For structure or equipment that can be reused such as floor, wall, lights, etc., it is better to make the most appropriate storage box based on the different sizes of these elements; it is best to design a map and know their different volumes, which will help you choose the most appropriate vehicle, same as for storage.
C: The most reasonable is no storage, if it is always being used for an exhibition somewhere, with only storage which is the lowest cost. Improvements can be incorporated during the next building.

H: After all, there are few opportunities for constructors to use these components again.

Z: Could only do analysis on specific issues.

5-6-7 What do you think is the ideal connector method for demountable construction?

Prof. Schierle: Bolted, rather than welded connections would facilitate assemblies. The best connector would be a snap-on device, for assembly without tools.

Prof. Dai: It is ideal to utilize bolted connections.

Prof. Jiang: Depending on the requirement of structure, for the position required, steady or standing load bearing where bolted connection is needed. Only in difficult positions can riveting, welding or anchor bolt connection can be chosen. For a grid structure the ideal choice could be spherical joints; for partial, temporary and adjustable joints some special fastener could be a solution.

G: Of course, it is a bolt, welding is not easily removed.

C: Bolting and riveting.

H: Bolt connecting.

For this question, more than 90% of those who answered opted for bolted connecting.

5-6-8 What do you think are the materials/components for a demountable system to ensure long term robustness?

Prof. Schierle: Steel for structure, plastic or aluminium for enclosure.

Prof. Dai: Steel structure is a must.

Prof. Jiang: Aluminium alloy and steel could be an ideal choice. Because there are many redundancy elements in most special-shaped structures, it will, therefore, be sufficient to pay attention to the monolithic stability of structure only.

G: Combination of steel and wood structure.

C: Using PVC in non-load-bearing parts and wooden structure which is wrapped with hard materials—stainless steel in load-bearing parts.

H: Steel.

J: Steel alloy plus high-strength bolts.
For this question, more than 80% of those who answered opted for steel.

The results of the survey as summarized above suggest that many people are willing to see exhibitions housed in temporary, demountable structures. In most peoples’ minds these structures will be of steel bolted together. To look at what is actually happening in making temporary structures for a mega event, the following section looks at preparations for the 2012 London Olympics and how this has led to other temporary structures in the capital.

5-7 The London Olympics and Temporary Architecture

As the main event venue, the first piece of land of the Olympic Park in East London has been handed over to the 2012 Olympic Delivery Authority (ODA) to start preparation for construction. The ODA has claimed that London 2012 will be the first sustainable, zero-waste and low carbon games. According to the schedule the following arenas will be relocated after the Games: Water Polo, Hockey, Basketball, Fencing, Paralympic Tennis and Archery, the Greenwich Arena and the indoor Shooting hall. This suggests that temporary architecture is again receiving attention 36 years after Cedric Price’s trial project of the Inter-Action Centre in the Kentish Town area of north London in 1971. In fact, the August 2007 edition of the journal of the Royal Institute of British Architects had a main topic devoted to Temporary Architecture. London has always been cherished as a capital of fashionable design and it now seems there are about to be many demountable buildings and structures within its boundaries.

The LIFT (London International Festival of Theatre) is a demountable theatre project, inspired by Cedric Price’s Fun Palace. One of the design parameters is that the designers wanted a demountable building that looked permanent. It is a transportable meeting and performance space, but looks more like a permanent building.

The Urban Oasis, designed by the London based Chetwood Associates, is an installation. However, it is a structure
or a sculpture which has photovoltaic panels, a solar chimney, a wind turbine and a hydrogen fuel cell inside making it fully self-supporting in terms of energy in storage. Methanol is converted to hydrogen which is then used to generate electricity, producing only waste water. The fuel cell is needed to enlarge the energy output to about eight kilowatts. The installation has been travelling to and exhibiting at seven locations and gets dismantled each time. The function of the Urban Oasis is whatever people want it to be. It can be a watering-hole, light show, used for pumping water, for garden watering, and as an information point, as well as absorbing energy wherever it sits.

The ESS, or Edwin Shirley Staging supplies staging and sets including carrying them from city to city in a fleet of ESTs (Edwin Shirley Trucking trucks) to all kinds of touring shows. Starting his development of the modular systems to replace the company’s early scaffolding-based structures, Jeff Burke is a structural engineer by training but works with architects, such as Urban Salon Associates. The latter are owned by London architect Alex Mowat and they have worked together on a number of temporary structure projects with ESS. A series of temporary buildings produced by Urban Salon Associates and ESS, include a Washroom at Waterloo Road temporary office building, the Skyspace cinema complex at the Millennium Dome, rapid-assembly Greek schools, The RIBA's Portable Architecture exhibition, the Southwark One Stop Shop with Lifschutz Davidson Sandilands, the Event space at the Eden Project, the Australian Pavilion at Hannover Expo, 2000, with Tonkin and Zulaikha, and the Chanel pavilion with Zaha Hadid Architects. This extensive list suggests that temporary structures can be used for most types of building. At the moment Jeff Burke is thinking about the reuse of 170,000 extra temporary seats and other temporary facilities after the 2012 Olympics. Unlike Sydney, Athens and Beijing, which all opted for permanent facilities; London is seeking the use of temporary structures, as discussed earlier in more detail in this thesis.

No doubt, as the Crystal Palace and Brompton Boilers are products of the Industrial Revolution, today’s new developments of temporary architecture are the results from the increasing threat of diminishing natural resources. However, as long as these demountable building can reach higher aesthetic and functional standards, they can still stand for ever. The history of the Crystal Palace and Brompton Boilers has proved that such buildings can last. The Japan Pavilion of Expo 2000 Hannover, Germany (Fig.5-5) has proved it materially, and the Yuanda (Broad) Pavilion which was specially

209 RIBA Journal, Kings of the road, August 2007
built as an exhibit for Expo Shanghai 2010 has also shown it technically. The latter is discussed in more detail below.

5-8 A Pavilion that Embodies the Idea of Environmental Protection

The Yuanda pavilion was the 17th and final corporate pavilion erected at the Expo site and was completed within 24 hours. Fu Lixin, the man in charge of the construction of this six-storey, 3200-sq-m pavilion said “We’ve been preparing for two months, but producing the prefabricated parts took us less than a week…This is the way to build houses in the future. The building itself will be the largest exhibit at Expo 2010.” He added that most of the floors were completed within 30 minutes and the job finished by 10 pm the same day.

As a sustainable model, the Yuanda Pavilion adopted the “Zero Tolerance” model for the insulation in its walls and windows, and for its ventilation. Its energy consumption is about 20% of that of a traditional building of this type. Meanwhile, the materials it uses amounts to being a sixth of those found in similar modern buildings. Featuring 100% factory manufacture the Yuanda Pavilion also meets the requirements of the low-carbon and environmental protection policy. Apart from that, the Yuanda Pavilion is designed to have a healthy indoor environment, in which the air is refreshed three times every hour, using a new low energy air conditioning system, thus guaranteeing air quality in the pavilion. The Pavilion also contains anti-seismic features, namely its diagonal bracing and light weight. Damage brought about to building structures by earthquakes is mainly caused by horizontal seismic forces. Therefore, the seismic force born by parts of a building’s structure build up while the gravity

load of the building structure increases. To save the structure from large-scale destruction, the building structure must effectively consume the energy released by an earthquake and the design of the Yuanda Pavilion allows this to happen, as discussed below.

a) Around and in the middle parts of the Pavilion, there are at intervals a certain number of steel structural elements working as diagonal bracing, which form an improvement on the traditional bracing structures. Bracing structures of common buildings are in the form of pillars, which can handle vertical loads well, but are quite poor in bearing the horizontal loads of seismic forces. In order to solve this problem, diagonal bracings are added around and inside the load-bearing pillars. These branch-shaped diagonal bracings can consume the energy released by an earthquake, guaranteeing the integrity of the vertical load-bearing parts, and thus preventing the large-scale destruction of the structure. In this way, the anti-seismic function is greatly strengthened.

b) The construction of the Yuanda Pavilion uses no bricks. Instead, the major pressure-bearing parts are all steel. In addition, the concrete floor slabs also embody new technologies, which help to integrate the ceiling with the upper floor slabs to form a unified element 11.9m long, 3.9m wide, and 1/6-1/3 as thick as traditional concrete floor slabs. As a result, the dead weight of the building is drastically reduced, which in turn reduces the horizontal seismic forces.

c) Apart from improving the structural design to resist seismic forces and reducing the dead weight of the building, the process of the construction of the Yuanda Pavilion is as easy as making a child’s block building: the six-storey building can be put up in one day. This is “factory” construction in which cranes take the place of construction workers due to the adoption of precast methods for the concrete building elements.

This Pavilion points to the future of building construction in a time when resources will be shorter and more expensive. Such construction will be the same as machine making on an assembly-line, which is both an accurate and energy saving process. The bonus from this approach is that the building is both better for the environment and better able to withstand earthquakes.

5-9 Analysis of Results from the Survey

From the answers given by the participants in the survey it would seem that, with some exceptions, most people are sympathetic to the idea of demountable exhibition buildings and some people also
appreciate the need to find a new way to reduce the waste that comes with having short life buildings. This suggested that it was worth pursuing the idea of demountable exhibition buildings further.

The path from the Crystal Palace to the Yuanda Pavilion also suggests the ways of building ephemeral exhibition building using the ideas of prefabrication and demountability are gradually becoming more acceptable, and more popular. Most importantly, the survey online as described above received a considerable number of animated responses, some of which have been included here, and some web pages which have carried the questionnaire survey have been read more than two hundred times, which clearly shows that people are both interested in exhibitions and the sort of buildings that are appropriate in a resource short future.

The promotion of demountable expo facilities should result in a move to an efficient and environmentally friendly world. More importantly, this type of building will invariably make a significantly lower impact on the environment by reducing the event’s permanent footprint, material and energy wastes, and bringing into focus viable recycling within the context of crowed city land.
CHAPTER 6  TIBETAN TENTS: FROM MOBILE HOUSING TO EXHIBITION HALL

6-1  A General Overview of the Black Tent

In the search for a new form of exhibition building that will reduce environmental impact, it is important to search out historic precedents. Although the Crystal Place of 1851 is heralded as the first international modern exhibition building, the holding of fairs for trade and as places of entertainment has a much older history. Many of these historic fairs used demountable buildings in the forms of tents and booths. However, in one part of the world these tents were very large in size and their use is still current. They have therefore formed an important part of the precedent research for this thesis.

The black tent as a specific tent type is used by the Jews, Bedouins and other Arabs, and a hundred other tribes scattered over Africa and Asia including Tibetans. As an ancient structure the black tent’s birthplace is probably somewhere near Mesopotamia. Its earliest origin has been linked to the domestication of goats and sheep from 9000 B.C. to 8000 B.C., as these animals provided the materials for the tent cloth. However it was not until the domestication of the donkey (4000 B.C. - 3000 B.C.) that these early nomads begin to make a break from their traditional way of life towards a settled agriculture, although during this period people probably led a semi nomadic existence. The donkey had worked as an important pack animal for people living in the Egyptian and Nubian regions as each animal can easily carry 20% to 30% of its own body weight and donkeys can also be used as farming (traction) and dairy animals. By 1800 BC, the ass had reached the Middle East, where the trading city of Damascus was referred to as the "City of Asses" in cuneiform texts.

Due to the donkeys’ carrying ability people could only travel limited distances and over suitable terrain as the animals needed access to water. A final break was made when the domestication of the camel happened around 3000 B.C. to 2500 B.C. With the help of the camel (the ship of the desert) the nomad could roam through the desert to find

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211 University of Sheffield, National Fairground Archive, see http://www.nfa.dept.shef.ac.uk/history/charter/index.html
pasture for his flocks. The camel could carry greater loads than the donkey so the tent, the portable home of the nomad, increased in size. The black tent and the camel moved out of its Middle Eastern homeland and into new territories until it reached the African Atlantic coast on one side and the eastern border of Tibet on the other.

Structurally the tent embodies a common essence: it uses very little wood in its construction, and it is a tensile structure. In the black tent, the weight of the tent cloth and the great tension created by stretching the cloth is concentrated over the few vertical poles. This means that the cover and frame are reciprocal as neither can stand without the other. It is this interdependence that makes it possible to use only a few poles in contrast to other structures that have free-standing frames such as the tipi and yurt. Such a feature makes the structure a significantly more lightweight and mobile collection of components. As the tent appeared in different territories and climate situations, it began to show more personality or multiplicity. As the black tent spread it was adapted to fit each environment that it entered. In mountains where there is some rainfall, the roof was steeply pitched to shed rain. In the desert it was flattened and lowered to shield its inhabitants from the sun and sandstorms. In a hot country, it was made open to allow the air to blow through. In cold lands it was completely enclosed. No shelter design has been so thoroughly adapted to fit such a diverse range of environments.

Because the ever changing environment and living conditions determine the form of the tent, there are two basic types of black tent. The Arab type is used by the Bedouin tribes of Arabia, Iraq and all tribes to the west of them, who adopted the black tent as a dwelling. This tent cloth is woven from pure goat hair or from a mixture of goat and sheep or camel hair. The woven cloth breadths are sewn together, the number and length depending on the wealth and status of the tent owner. The Arab type has the addition of tension bands (trigas) sewn across the cloth breadths. Ropes attach to the tension bands so that the main pull of the ropes is across the seams, exactly the opposite to that of the Persian tent. The tension created by the pull of the ropes is concentrated in these reinforced tension bands. The bands, the poles that stand under them, and the rope stays all create an independent support system underneath the tent cloth. A variety of versions of tent made on this theme can be found across this region from the shallow roofed desert tents of the Bedouin to the pitched roof Moroccan and Ouled Nail tents of the Berber tribes of the Atlas Mountains.
The Eastern or Persian type tents are used from Iran to Tibet. They are of the simplest construction, being a series of cloth breadths sewn side by side, with loops on the edges for the rope stays. When the tent is set up the main pull of the ropes must be length ways (in the same direction as the seams) for if the pull were across seams, it would pull them apart. The poles are generally placed under seams, which can take the stress at this point. Examples of these structures may be characterized by the traditional dwellings of the Kurds, Qashqai and the Tibetans with their traditional yak-hair tent which they call ba-nag.

The process from first production to maturation of architectural form is an important expression of national characteristics. In the early formative stages the architectural form is closely related with the natural environment and specific conditions for survival. In the later stages of development it is more associated with a nation’s collective wisdom, degree of enlightenment and aesthetic taste. The Tibetan black yak-hair tent is an indigenous mobile building formed by local conditions, local materials and the purely manual construction techniques passed from generation to generation. It is not only a crucial part of the Tibetan way of sustaining life on the land, but also a demonstration that this kind of production and lifestyle are related to economic fundamentals.

6-2 Qinghai-Tibetan Plateau’s Sky, Earth and Life

6-2-1 A vast and sparsely populated area

Generally, the Qinghai-Tibetan Plateau with its very high overall elevation (an average elevation of over 4,500 metres) is known as the “roof of the world” and “the third pole of the earth,” as some of the harshest geography on the planet is found there. It is a vast, elevated plateau in Central Asia covering most of the Tibet Autonomous Region (TAR) and Qinghai Province plus parts of Gansu, Sichuan and Yunnan Provinces in China. It occupies an area of 2.5 million square kilometres about four times the size of Texas or France. According the 1990 official census, there are 4,594,188 Tibetans214 living on the plateau, with 53% living at an altitude over 3500 metres. A large number people (about 600,000) live at an altitude exceeding the average 4500 metres in the Changtang-Qingnan area. Compared with the population density of 34.8 persons per square kilometre in Texas215 and 115 persons per square

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215Texas Quick Facts from the US Census Bureau, US Census, 2006
kilometre in France.\(^{216}\) Qinghai-Tibetan Plateau’s population density is very low at only 3 persons per square kilometre.\(^{217}\) The Ngari (Pinyin: Ali) Prefecture, located in the western Qinghai-Tibet Plateau with an average population of 0.23 persons per square kilometre, is the region with the lowest population density in Tibet and China.

Although the Peruvian city of La Rinoconada at 5100 metres above sea level has been named by National Geographic in 2003 as the highest permanent human habitation\(^{218}\) it is not permanently occupied. The settlement of about 30,000 people located high in the Peruvian Andes is home to people who survive the lack of oxygen and high altitudes to work in the gold mine there. The town is situated at the base of a still operating gold mine, where almost all of the inhabitants work. Most residents, however, come and work for short periods of time before descending to lower, more hospitable elevations. It was reported by the China Tibet Information Center that the world’s highest village, 5,070 metres above sea level, is located at Tui Village in Dalong Town, Lhoka Prefecture\(^{219}\) in the Tibet Autonomous Region of China. In Northern Tibet, the town of Nagqu governs more than 40 million square kilometres of the vast territory at the average altitude of 4,507 metres of Nagqu Prefecture, and could be the place of the world's second highest cities in the heart of the Plateau. As a northern Tibetan livestock and native products distribution logistics center and highway hub in the Tibetan pastoral areas, the town itself has an area of 0.4 square kilometres and jurisdiction over 28 villages (neighborhood) committees. It had a population of 17,000 in 1996,\(^{220}\) mostly Tibetans who have lived there for generations. There are 12 industrial enterprises, mainly ethnic handicrafts and raw materials processing industries. Considering many tourists complain about altitude sickness when visiting places like Denver, Colorado, located just over one mile or 1609 metres above sea level,\(^{221}\) it would seem nearly impossible for anyone to actually survive at an elevation of almost 4,507 metres. In fact, Nagqu town sits fairly close to the maximum altitude of human survivability. There are many

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\(^{216}\) French Land Register data, which exclude lakes, ponds and glaciers larger than 1 km\(^2\) (0.386 sq mi or 247 acres) as well as the estuaries of rivers.

\(^{217}\) Wang, G. et al. Influences of alpine ecosystem responses to climatic change on soil properties on the Qinghai–Tibet Plateau, China, *Catena*, Volume 70, Issue 3, 1 August 2007, Pages 506-514

\(^{218}\) Anthony, M. (2005), *Altitude of Human Survivability, Maximum (Vertical Limit)*, The Physics Factbook


\(^{220}\) 那曲县人民政府, 那曲县委宣传部, 那曲在线 http://www.naqu.net/

arguments about the maximum altitude of human survivability all over the world, but one point is crucial;

...the main reason why communities do not live higher in countries like Nepal and Tibet is that there is little point in doing this. Crops and vegetables will not grow at these great altitudes, and it is not possible to graze livestock for 12 months of the year because of the lack of fodder. Therefore, there is no advantage in trying to develop a settlement there. By contrast, if there is another economic activity such as mining, it is indeed possible for a community to live at an altitude as high as 5100m.

So the altitude of the highest permanent human habitation is probably determined by economic factors, rather than solely by human tolerance to hypoxia.

6-2-2 A harsh natural environment

The Northern Tibet plateau is different from any other grazing land in the world. Research has so far failed to convert this alpine land into arable farmland and orchards. In this non-farming land, the nomad could be the only solution to the need to subsist. With their permanent flocks of sheep and herds of cattle, the nomad becomes an element of nature, working in partnership with the sun, moon and snow, or as an adjunct of the natural world. A tent plus a group of cattle and sheep could be all that is needed for pastoral survival. Although the pastoral life year after year is not totally stable its pattern is reasonably predictable and hence it is a tranquil way of life. What interrupts the pattern is all kinds of natural disasters. In addition to floods and volcanic eruptions, Northern Tibet gets almost every evil: drought, insects, wind, hail, snow, debris flow, avalanche, earthquakes and fatal lightning strikes. Among these the snow fall in 1985 was very harmful. Between October 17th and October 19th heavy snow fell continuously for 41 hours in the Nagqu Prefecture. There was suddenly a one metre thick blanket of snow north of the Tanggula Mountains. The sudden snowstorm caught the herdsmen by surprise. It endangered life over an area of 150,000 square kilometres, and involved nearly 74,900 stricken herdmen and 3,000,000 domestic animals in North Tibet.

Another snow disaster in Tibetan history lasted eight months from September 1989 to April 1990, when continuous blizzards occurred in Baqen, Lhari, Biru, Bangor, Nagqu, Wenbu, and Sogxian. In this period 13 townships had their biggest snow disasters in history. Snow fell on over 120 occasions, and the entire pastures were covered to a depth of between 50 and 100 cm. This affected 40,316 families, 222,300 people, and 5,097,500 livestock with a death toll of 980,000 animals. In some places the mortality rate was as high as 30%. Disasters caused direct economic losses of RMB 791 million.

The snow covered pastures had sustained low temperatures below an average minus 30 degrees Celsius. Because the domestic animals did not have grass to eat for a long time, there was the phenomenon of live livestock eating dead livestock, big livestock eating small livestock, and cattle and sheep eating tents in some hard-hit areas. The livestock mortality rate reached 50 - 70% at the partial township of Amdo and other hard-hit counties, and in some villages and households the mortality rate was an average 80-90%, meaning some places and households had no domestic animals left.

The pasture in northern Tibet may be the world’s worst pasture. In particular, the western pastures at 5000 metres above sea level are semi-desert land. Fortunately, allegedly due to the strong sunlight and other reasons, the forage nutritive value is higher, which can be seen as compensation. However, the insurmountable hypoxia affects and stunts the growth of the livestock and, thus the western cattle and sheep are much smaller in size than the cattle and sheep of the low-lying eastern parts of Tibet.

6-2-3 Human life in the highest lands

Tibet has had a backward (in modern terms) economy for a long time, owing to its fragile economic basis and tough natural conditions characterized by high altitude, cold climate, thin air and remote location. Especially in Northern Tibet, the high elevation has provided some very notable challenges to the indigenous peoples in the region, who must eke out a living from land which is often barren and difficult to work with. The world understands very little regarding Northern Tibet and the North Tibetan, partially because Northern Tibet is isolated and insulated from the rest of the world. The North Tibetan also has little time to think about things outside the need of survival. Although

225 China Tibet Information Center, Central government’s special support to Tibet, (中央对西藏的特殊扶持) 05/19/2005
226 Gu, A., Eco-geographical Distribution and Food Evaluation of Major Forages in Sedge Family in Tibet, Beijing, Grassland of China, No.4, 1989
Tibet is one of the five main pastoral areas in China, and the Northern Tibet area is the most important pastoral region in Tibet, what the Lhasa residents eat is mostly powdered milk and meat from inland China. Yogurt made by the Qinghai, Gannan and Sichuan factories is also drunk, although the whole of Tibet does not have comprehensive dairy and meat processing plants like the Guoluo Tibetan Autonomous Prefecture in Qinghai.\(^{228}\)

Excluding other factors, the most relevant Tibetan characteristic is the harsh natural environment. Outsiders react in two ways; the first in response to the power of the natural environment is to realize that survival is so difficult that modern development is impossible; the second is to see the nomadic way of life as something romantic that should be kept rather than changed. However these are ideas from outsiders; pastoralists generally do not consider the problems of their life in such ways. They see life as a continuing pattern; if life for the elder is like this, then that of the offspring should also be like this. Following this idea it is easy to see why the custom of Tibetan Celestial Burial\(^ {229}\) has lasted for a thousand years. The process of Celestial Burial is, in the Tibetan mind, sacred and not something to be feared. Although in modern Tibet the Chinese central government has invested heavily in the establishment of a modern crematorium, very few bodies are sent to the crematorium because of a thousand years of customs, with tower burial, ancient cremation, water burial and tree burial being preferred in different areas.

Tibetans are good at using a variety of singing and dancing to express their various emotional and psychological states which are difficult to express through language. There are three major types of Tibetan folk song and dances in northern Tibet today: Guozhuang,\(^ {230}\) Raba,\(^ {231}\) and Xianzi.\(^ {232}\) At present the most active land sector for Northern Tibet singing and dancing is the edge of the

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228 According as the news issued on 01-19-2009 by the web site of the Tibet autonomous region people's government, Nagqu prefecture has already reached an agreement with one of the China's dairy giant companies Yili Group, and Yili Group is involved in the ongoing preparatory work for a dairy plant in Nagqu. 西藏自治区人民政府网站: 牵手“伊利”打造西藏自治区乳业产业链, 发布日期:01-19-2009.

229 Celestial burial: Tibetans believe that their ancestors came from heaven then went back to there after death; the deceased's body is left on the mountainside to feed the vultures, who in turn take the soul to heaven.

230 Guozhuang also called Zhoi (dances) is prevalent in places like Qamdo in Tibet and Kangding in Sichuan Province. The dance names, melody and movements vary in different places.

231 Raba means "roaming artist" and is prevalent in Tibet's Qamdo, Gongbu, Nagqu and other localities, also in Yunnan, Sichuan, Qinghai, Gansu and other Tibetan-inhabited areas.

232 Xianzi (meaning songs and dances) is also known as "Ye"or "Xa", with the most typical kind Batang Xianzi in Ganzi, Sichuan Province.
semi-agricultural or semi-pastoral areas. In Sogxian and Lhari County in the east, people claimed that what they were singing and dancing came from the Qamdo; while on the southwest side of the Wenbutownship and in other places, people said that their songs and dances came from Xigaze. Bangor County in the heart of northern Tibet is a purely pastoral area, and it is said Bangor has the typical herdsman’s dance with very good movements of legs and feet.

In contrast to most dances of other Chinese ethnic minority groups, especially Guozhuang, Tibetan women are the foil in the dance and their action is modulated, beautiful and dignified. Tibetan men are the centre of the dance. The rhythm, frequency and speed of the dancing movements of the men are reminiscent of the western tap dancer. Male dancer action is very bold and rough, obviously with an ancient courtship legacy and the great beauty of masculinity. Until now it has always been a puzzle to the audience, as even dancers do not know the real meaning of the dance. They only know that it was learned from their elders, and is passed on from generation to generation. So whenever they are happy and dancing they are just repeating the pattern from their ancestors. This is the same as the nomadic way of life and the tent structures on which it has depended. Because it is inherited it is never questioned.

Deep inside the grasslands, traditional singing and dancing are almost extinct. There only greatly simplified actions are used, with the dancers in a circle, slowly moving hands and feet. On the pastures with altitudes near 6,000 metres, the shepherds simply stated that they neither sing nor dance. There are two main reasons for this phenomenon. The first is the fact the most important thing at this high altitude is breathing and all breathing is for basic survival; the other is that in the sparsely populated parts of the Plateau, finding dancing partners could mean a journey of more than hundred kilometres. So, in the highly fragmented and closed high-altitude pasture lands, cultural activity

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233 Wenbuin southern Nyima County is the only township with a small amount of cultivated land. People live by animal husbandry, though they still have a small number of kinds of crops such as barley and peas. Here is one of the original birthplaces of the Tibetan Bon religion. Wenbu people are good at impromptu dance and sing for self-entertainment.

234 Xigazê city; (Chinese: 日喀则), is a county-level city and the second largest city in Tibet Autonomous Region. It is also the administrative centre of modern Xigazê County in the Xigazê Prefecture, a region of Tibet.

235泽吉：略谈康区果卓、热巴、康谐三大舞的艺术特色,西藏艺术研究, 2009-07-07 (Sawakichi, A Brief Discussion of the Art Characteristics of Three Dances in Kham Region: Guozhuo, Raba and Kang Xian, Lhasa: Tibetan Art Research,2009-07-07)

236 Li, R., Wenbu: the only Bon village in the west of Northern Tibetan, The Lamp Pursuing Life - Spiritual Dialogue with 99 Tibetans, Beijing: Unity Press, January 2003 edition. 李路阳: 《追寻生命的灯——与九十九位藏民的心灵对话》藏北西部的本教村落文部,
almost disappears. This is because hypoxia consumes much energy and can be life threatening. Even in lower attitudes or on the edge of the semi-agricultural or semi-pastoral areas, either weather or space limitations restrict the full enjoyment of Tibetan dancing. As mentioned before, the weather in this highland is uncertain; unsettled weather is typical, with rain and hail and sunshine coming one after the other.

Composition of the Reba dancing team generally has the family as a core, or sometimes several family members cooperate to form a team of 6 to 30 persons. Both Guozhuang and Xianzi are combinations of singing and dancing with a pivot circle. The Samsara circle is the most basic aesthetic of Kang-pa’s religious and folk dance, which embodies the highest spiritual realm and perfect pursuit of the Tibetan people. The commonalities of the three major types of Tibetan folk songs and dances are the collective dances that need large open spaces. In reality, as the Tibetan economy grows, people’s requirement for self-entertainment is increasing. Around 1985, ballroom dancing became fashionable in the whole of China. Many people thought Lhasa was very isolated but in fact, because it is near to Chengdu and had direct connection to Guangzhou by air, Lhasa was more up to date with changing fashion than most regions in China. When the Tibetan Mass Arts Centre in Lhasa held its first ball, fighting arose because many people were unable to get in. As the main recreational facility in Nagqu town, Nagqu Mass Arts Centre was packed with people every night. The dance party always ended with pastoral Guozhuang dancing, under a magnificent turning lamp with the pastoralists enclosing a big circle, which symbolizes satisfaction and happiness. Combined with a chorus, solid and slow dance steps connected with the land through the red lacquer wood floors. At that time people often felt that the room was too small to thoroughly enjoy themselves. From an evolutionary point of view, content and form go hand in hand, so when the old form cannot match the new content, it should adjust or change and synchronize with the development of content. So the growth in popularity of self-entertainment or leisure activities has promoted the birth of new form to contain them. The old black tent, the former site for most local entertainment, is facing transition.

6-3 The Yak - the Irreplaceable Animal for Tibetans

Because nomadic settlements are scattered far apart and the natural high alpine and anoxic conditions are quite serious, the lives of the herders entirely depend on some kind of animal or vehicle for mobility. However, nature is fair and has created the most remarkable animal for the Tibetan environment, the yak. The yak is aptly referred to as the boat of the plateau or the camel of the snow
and is also deeply involved with the living culture of the herdsmen. When people think of the animals of Tibet, the yak will probably be the first that comes to mind. There is a proverb in the Plateau which says that a Tibetan packs everything on the back of a yak. No one can deny that the yak is the lifeline of all the indigenous people of the highlands.

6-3-1 The distribution of the yak

Yaks were first domesticated from the Bos Mutus about 5,000 -10,000 years ago by the Jiang people who were the ancestors of modern Tibetans. Tibetans have a long history of using yaks. Experts believe that the history of China’s yak industry is at least 4,500 years old.\textsuperscript{237} The distribution of the yak throughout the world has been nearly always in areas with a high elevation, low atmospheric pressure, a long cold season, a short warm season, hypoxia, and no lush forage grasses. These equate to the extremely harsh steppe zones with an altitude of more than 3,000m, where the oxygen content in the air is only $1/3 \sim 1/2$ of that at sea level.\textsuperscript{238}

In addition to the alpine characteristics of the plateau region, yak distribution has also been associated with low-temperatures and bitter cold. According to the studies of Dou, Yaozong et al,\textsuperscript{239} the most suitable climatic and ecological conditions for yaks in warm seasons are those where the monthly average temperatures fall between 5-13°C, the extreme maximum temperature is <27°C, the annual precipitation is >250mm, and the coefficient of humidity\textsuperscript{240} is >1.0; while in the cold season the coldest monthly average temperature is >-12°C, and the extreme minimum temperature is >-36°C. The acceptable climatic and ecological conditions in the warm season are when the monthly average temperature is 19°C or so, the extreme maximum temperature is <32°C, the annual precipitation is >150mm, and the coefficient of humidity is about 0.7.


\textsuperscript{238} Yuan, Q. Y. with supervisor Xie, Z., Cloning and Modeling of Yak Hemoglobin, the doctoral dissertation of the Nanjing Agricultural University, China, Animal Genetic Breeding and Reproduction (Professional) 2005.


\textsuperscript{240} The coefficient of humidity is a meteorological term also called the humidity coefficient. It is a measure of the precipitation effectiveness of a region; it recognizes the exponential relationship of temperature versus plant growth and is expressed as humidity coefficient = $P/(1.07)^{t}$, where $P$ is the precipitation in centimetres, and $t$ is the mean temperature in degrees Celsius for the period in question; the denominator approximately doubles with each 10°C rise in temperature.
The yak has evolved to survive in tough environments. It is said by Tibetan herders that yaks living below 4,000 metres may get malaria, parasites or other diseases, and those below 3,000 metres reportedly suffer disruptions to their breeding cycle. Yak physiology is well adapted to high altitudes. The animals have larger lungs and hearts than those of cattle found at lower altitudes, as well as a greater capacity for transporting oxygen in the blood. The long, thick hair of the yak insulates the body from winter temperatures that can drop to -30°C (-22°F) or colder. Most yaks are black, but it is not uncommon to see white or grey ones, especially on the grasslands of northern Amdo (modern day Qinghai province). Tianzhu Tibetan Autonomous County in Gansu Province, located in the northern edge of the Qinghai-Tibet Plateau, is China's area for producing the rare and precious white yaks.

As mentioned before Qinghai-Tibet Plateau and the surrounding vast area known as the roof of the world are both the yak’s birthplace and its main breeding area in the world. Eighty-five percent (or about 12 million) of the world's yaks live on the Plateau and of this total ninety-three percent are in Chinese territories. According to the most up to date investigation of yak numbers in China, Qinghai has the highest population of 4,900,000, accounting for 38% of the total number of yaks; Tibet is the second with 3,900,000 animals, accounting for 30% of the total; Sichuan is the third with 3,100,000, accounting for 23% of all yaks; Gansu with 880,000 is fourth, accounting for 7%; Xinjiang is fifth with 170,000, accounting for 1.30%; and Yunnan with 50,000, accounting for 0.40%, is sixth.

6-3-2 A high altitude vehicle – the yak as an important means of transport

Before China produced the modern motor vehicle, livestock including horses, mules, donkeys, cattle, sheep, dogs, elephants, camels, and reindeer served as the means of transportation. On one hand they acted as a means of haulage, while also serving as a means of human transport especially horses, mules and donkeys. In the Qinghai-Tibetan area, owing to the extremely tough environment, most animals have difficulty surviving. Thus the yak has played a widespread and vital role in


243 Hu, Y. (Feb.9, 2010), China's Present Situation and Prospect of Yak, the Tianzhu Wide-ecological Breeding Base for Green Wildlife in Gansu Province. 胡玉龙:我国牦牛发展现状与前景分析. 甘肃省天祝全生态绿色野生动物养殖基地
transportation; it is known as the "Altitude Vehicle" and has a well-deserved reputation for reliability and excellence.

The yak is a special form of livestock with unique idioplasmic characteristics. These are the results of natural selection under the cold highland climatic conditions. The yak has a thick coat of long, dense and coarse hair with a very small area of skin exposure and has less sweat secretion than other animals. It has a good appetite and is herbivorous. That is why it is able to resist cold and hunger and can sleep lying on snow and ice and not feel the cold. Except for the Jiulong yak, the normal physique of the yak is not big but strong with short limbs and large, hard hooves. This makes the animal good at traversing mountain roads and even bogs or marshes when carrying a large load. The yak's trachea is short and thick and it has a well-developed chest. It can breathe quickly and has a high level of large, red blood cells and its blood hemoglobin concentrations are very high, which has resulted in its excellent carrying ability in the thin air between the mountains and hills. It is only the yak, compared with other livestock, which can walk continuously for up to 20-30 days. The Annals of Sungpan County, which were published in the thirteenth year of the Republic of China in 1924, praised the yak’s ability with an emotional language: “The yak … traverses across the world of ice and snow without any fear of cold. Even when the yak does not have water and grass for several days, it can still carry heavy loads on its back unflinchingly. What a real treasure of livestock to the frontier that is!”

It is precisely because of the advantages and characteristics of the yak mentioned above, that internal contact and exchanges between the Tibetans and other ethnic groups were mainly carried out by yak. Yaks were also used in teams to form a train used to transport large loads. Among a herd of yaks, there is one yak that leads the way and always goes in front. The leading yak wears a string of beads, which has been blessed by a living Buddha, and is intended to keep the whole train safe. Some yaks are also covered by red blankets representative of their merit and their brave contribution to life on the Plateau. Before departure, the Tibetan shepherds often recite the scripture of Tibetan Buddhism (commonly

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244 Zhang, Y., *Effect on productive performance by using Jiulong yak to improve other yak*, SessionII : Genetics and Breeding, Domestic Animal Improving Station of Ganzi Prefecture, Kangding, Sichuan, P.R. China

245 Songpan county in northeast of the Aba Tibetan and Qiang Autonomous Prefecture in Sichuan Province is an ancient city of China. Once being a tea and horse trade and distribution center between Sichuan, Gansu, Qinghai and Tibet, the plateau city is located in the middle of the Minshan Mountains and belongs to the eastern edge of Qinghai-Tibet Plateau.

246 *Text proper in Chinese: 民国:《松潘县志》“行冰天雪窖中不畏冷，虽数日无水草，犹驮二百余外，行走不衰，真边地之宝畜也。”*
known as Lamaism) and some even remove the red silk from their head and tie a knot to judge whether this is an auspicious day for the journey. If the knot is too tight it indicates an unlucky day, and so the herd does not leave but waits for a more auspicious day.

When the yaks are on the way, the shepherds generally ride horses alongside, holding whips and crying out encouragement to the herd. When a shepherd cracks his whip he issues a crisp sound indicating the herd should walk in a certain direction and wielding the whip toward that way. If the herd does not obey him and wanders about aimlessly, the shepherd will fire a stone from his whip towards the head of the yak to give it a warning. On the way when the herd stops to rest, the yaks will be fed on salt and roasted barley. After the break, the shepherds blow whistles, and the herd will obediently start walking again. The shepherd’s baggage is very simple, a tent, a gun, a bag of dry food, plus a small replica of Buddha for protection. They walk about 20 kilometres each day before setting up camp. They scatter the herd in all directions in the camping area to search for water and plants. When dusk is approaching, a shepherd blows a whistle and the herd conscientiously returns. A wooden stake is nailed into the ground to which the yaks are tethered. Shepherds without tents will lie down underneath the yak’s belly thus taking advantage of its warmth and avoiding wind and rain. In more permanent arrangements, yaks are kept tied up outside the tent using lines of rope that are made secure by two wooden stakes driven into the ground. Each line of rope will have 8 to 10 small loops which are put around one of the yak’s feet at night (or tied through the yak's nose). A few dogs will also be kept tied up outside the tent. Large piles of dried yak dung are stored close to the tent, and form the first barrier against wolf attack and severe weather.

There were no highways in Tibet until the 1950s. Economic and social contacts within Tibet and its contacts with the outside world depended solely on human power and pack-animals, as well as post roads. With Tibetan social and economic development and increased demand for transport, the modes of transport in Tibet changed from the simple human and yak combination to more organized and varying scales of commercial transport consortiums consisting of yak troops.

Nowadays, even with the advent of car, rail, and air transport in the snowy mountainous grasslands of the vast Qinghai-Tibetan plateau, yaks still play an important role in carrying goods. During the first time a Chinese mountaineering team climbed Mount Everest from the North Slope in 1960, 40 yaks
from Qusum Village in Tingri County of the Shigatse Prefecture went back and forth several times from the 5900 metres above sea level base camp shipping many loads of mountaineering gear and scientific equipment to an elevation of 6500 metres at the advance base camp. The yaks had become the main means of transport to replace the tasks generally done by climbers. Without this high altitude vehicle, the yak, it would be impossible to form a large mountaineering team because it is very difficult to ensure a full supply of goods high above the base camp depending solely on manpower. The height of base camp is the highest point that motorized transport can reach but the height of advance base camp is the yak’s limit.

Yaks are sturdy, sure-footed and perfect for using as pack animals to cross high mountain passes. They can easily carry loads of 70kg or more along rough and steep mountain trails. For centuries yaks were used to carry salt from the Changtang (northern Plateau) to towns across Tibet and even across the Himalayas into the Dolpo region of Nepal. The salt was traded for daily necessities. Yaks can be used as pack animals from the age of two years and often live for 20 years.

6-3-3 Other economic values of the yak

Besides being excellent pack and riding beasts, domesticated yaks are multi-purpose animals providing milk, fibre and meat. They can pull a plough, and even their dried dung is an important fuel. In addition, yak hair is woven into yarn and used to make tents and ropes. Yak hide is used to make boots and boats. Yak meat is eaten by nearly every Tibetan family. It is high in protein with only one-sixth the fat of regular beef. In the summer months it is dried, but in winter it is often eaten raw. Yak milk is high in fat and is usually made into butter, yogurt and cheese. Even yak bones can be processed into bone powder and bone glue, the former for feeding animals or for fertilizer and the latter for industrial use.

Although from an economic point of view it is not worth keeping a horse, there will be at least one horse in each Tibetan household. In Tibetan eyes, the horse is a symbol of elegance and is only used for visiting friends and family members or when undertaking certain tribal affairs. In contrast the yak is affectionately called the "Nor-Bu", which means treasure. Once bartering was very popular in the

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247 Mount Everest's northern slope located in Tingri County of Shigatse Prefecture. The southern slope is situated within the boundaries of Nepal. The traditional mountaineering route of northern side has strong winds and is longer. The southern slope journey is relatively short, but the slope is quite steep.

248 Li, Y. (Writer and Director), Ma, T.(Camera) (2008), Memory of Mount Everest (middle) - Across the peak, video program, Tibet Television Station
Serthar region.\textsuperscript{249} During trading, the yak would be used as a standard for measuring the quality of other livestock and goods, as shown below.

- Horse - 6 yaks for a high quality horse; 5 yaks for a medium horse; 3 yaks for an inferior horse.
- Sheep - 1 yak for 5 medium rams; 1 yak for 4 ewes; 1 yak for 3 large, fat rams.
- Dzho - 1 yak plus a bull calf for a male dzho; 2 yaks for 1 female dzho.
- Ghee - 1 yak for 70 - 80 Jin\textsuperscript{250} of ghee.
- Barley - 1 yak for 3 - 4 Jin of barley.\textsuperscript{251}

So, the yak, in addition to being an all-purpose animal, served as money in barter transactions until sixty years ago.

Residents of the region rely heavily on pack animals like yaks, along with durable farm animals such as goats, and despite the hardship of life in this highland region of Asia, they have developed rich and colorful cultures with distinctive artistic traditions. The domesticated yak of Asia is smaller with a maximum 550 kg live weight for bulls and 350 kg for cows, while the wild yak could be more than 1000kg. Yak meat is of secondary importance as milk and hide products are more important to the indigenous peoples, since they could not exist without their tent made from yak hair, as discussed below.

There is no doubt that yaks are the most indispensable animals to the Tibetan people. Nomads keep yaks in herds of between 20 and 100. Yaks are always given names, but their names are different from the names given to people. They also add to the aesthetic value of the plateau and are sometimes decorated for riding and racing at festive times.

\section*{6-3-4 Tent - the biggest product made from the yak hair}

Yak hair is long, shaggy and has an under layer of fine wool. Each yak produces around 2.5 kg of a mixture of hair and fine downy fibre annually; high-yielding types may produce as much as 25 kg.\textsuperscript{252} The main types of yak hair and their applications can be divided into three major categories.

\textsuperscript{249}Serthar County is located in the northeast Ganzi Tibetan Autonomous Prefecture of Sichuan Province and has a complex terrain. Its average elevation is over 4,000 metres with grasslands, lakes, rivers. It is also the site of many splendid Tibetan customs. Most towns of Serthar area are pasture based.

\textsuperscript{250}Basic unit of weight measurement is used in China, 1 Jin is equal to 500 grams.

\textsuperscript{251}Gelek, L., 藏东牧民——人类学田野考察笔记 (Trip to Nomad Areas of Eastern Tibet—Travels of Anthropological Fieldwork)
1) Shaggy hairs (guard hairs/coarse hair): these grow on the yak’s chest, forearms, and sides of the body or the hind legs and are relatively long hair. The way the hair grows resembles an apron, and therefore it was called “skirt wool.” It is especially used for making cow rope, ties for putting up the tent, and reins for livestock. It is coarse with a diameter of 64.8 ~ 72.9μm, and an average length of 18.3 ~ 34cm.

2) Downy hairs (undercoat): this covering of short hairs lies underneath the longer outer hairs of a yak’s coat. This soft undercoat is used to make "yak cashmere" sweaters or spun into Pulu (hand-woven wool cloth, also known as Tibetan wool cloth, although the name differs from place to place) which is used to make bags and blankets. The rough belly hair is mainly woven into tent cloth and blankets. Heterotypical fibres\(^{253}\) have a typical diameter of 34.8 ~ 39μm. The diameter of undercoat fibre is 16.8 ~ 20.3μm; its length is shorter than the coarse hair at 4.7 ~ 5.5cm

3) Tail hairs: these are the longest hair of the yak. They are used to make false beards for traditional Chinese drama, and wigs and whisk are also made out of whole yak tails. Historically the tails were used as a tribute, and the white tail hair is more precious.

The fine downy hairs have been rarely used on the Plateau. Instead most of them are transported to eastern cities such as Shanghai, Tianjin and Beijing for processing into high-grade textile materials used in garment production. Most undercoat hair is in fact a mixture of heterotypical fibers and selected short length coarse hair together used as “down”. The downy hairs used by herdsmen are selected from the yak's abdomen, and the Tibetans usually used them to weave tent cloths.\(^{254}\)

Before starting to make a new tent, pastoralists will plan the size of the tent according to the general economic situation, the family size and the consumption of premier raw yak hair. Even a medium size woven tent may take 75 kg of yak hairs, while each yak can only produce an average 2.5kg of hair annually. Besides the number of yaks and other property owned by the household, the total ability for transporting the tent would have been the most crucial factor in the past. If the animals could not carry a heavy tent, the herds would be unable to move. From these factors it can be seen that nomadic

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\(^{253}\) Heterotypical fibers are also known as the intermediate type hair. Their fineness and other process values lie between the undercoat and coarse hair.

production and lifestyle are largely constrained by the external environment, economic conditions and materials available. Whatever the herders might want in terms of accommodation is constrained by these interacting factors.

The black yak hair tent of the pastoralists is the biggest handmade product in the Plateau. The first working procedure is teasing and selecting good yak hair. The most difficult work is the twisting and weaving of the Pulu. Those two procedures are completed by the women. This work happens after the women have finished their daily milking, cleaning, dung collecting and other household chores such as cooking and making tea. The twisting tool is a simple home-made spinning wheel made from cattle and sheep horns or wood. When they start twisting, the women spin the thread of Pulu with one hand, smoothing the hair with the other hand holding the wheel. The fine thread has to be twisted as tight and evenly as possible. Taking the time to twist a little every day, women gradually accumulate enough until they have sufficient to make a ball of Pulu to weave. When a warm summer is coming, they start to weave a piece of Pulu with simple equipment. In this way those more skilled at weaving can weave a three to four feet length in a day. Generally one person can only weave one roll of Pulu in a summer. Assembling enough Pulu to make a tent may take up to 10 years of effort. The finished rolls of Pulu are collected for the neediest household to solve its accommodation problems by sewing the tent cloth first. The tent cloth sewing is done by many men who work together so a tent can be sewn in one day. In order to be easy to carry when migrating, the tent is generally made of two or four big pieces, so that these can be connected and dismantled quickly. When a tent is broken up for migrating, the bull yaks carry the loads. Although the tent’s production is all done by hand with some extremely primitive equipment, the Pulu’s weft and warp threads are very tight and its texture is quite dense. So, basically it does not leak, although children are often warned by their parents not to touch the tent when it is raining.

Tibetan tent living practices have lasted for thousands of years and are still used today. From the viewpoint of materials, the ancient Tibetan people used a mixture of goat and yak hair to weave their tents, while today’s Tibetans use pure yak hair. However, the tent’s shape still retains its ancient character in addition to its name, and tent terms are more or less the same in different Tibetan regions.

6-3-5 Yak dung - an important link in the ecology of the Plateau
Nowadays even though some Tibetans get electricity from the grid or from solar panels and there has also been a major switch to gas burners, most still burn yak and cattle dung for heating and cooking. The fact that yaks are much loved can be seen by their owners calling them “biogas converters.” Generally about the size of a man’s hand, yak dung paddies are laid on a mud wall for drying before they are used as fuel. About 7,000 paddies are needed by a household to get through the winter. Since yaks only eat wild grass from a variety of pastures, when the dung is burned it smells cleaner and sweeter than domestic cattle dung and burns very hot just like wood. Compared with the possibility of piles of dung patties polluting their drinking water, burning the patties is much better and less harmful. The Tibetan practice of recycling dung, not only effectively solves the fuel problem in a convenient manner, but also effectively solves the excrement problem which may be caused by leaving dung on the grassland.

More importantly, if the excrement was not used for the fuel, the few trees that grow would have to be cut for fuel. Tibetans have made great contributions to the protection of their ecological environment. This embodies the Tibetan spirit of love for nature and the principle of harmony between human beings and nature.

In fact in most areas of the Plateau it is extremely difficult to grow trees and crops, and only wild prairie vegetation is widely distributed throughout the high and cold landscape. Firewood is in extremely short supply and the sparse population and the inconvenient transportation methods mean other forms of energy are not available. The herders have long been using animal dung and grass as fuel in order to maintain a minimum standard of living. In the Tibetan language yak dung is called “Qiuwa” which means fuel rather than excrement. Tibetan people do not think of the dung as unclean, they think it is very precious. In recent years yak dung has been selling in large quantities as a commodity, although this could significantly affect the ecosystem nutrient cycle.

Several years ago, a researcher thought that because of the struggle between man and grass for livestock excrement the lack of fertilizer was making the Tibetan pasture of lower quality, and the grassland was being degraded. Based on personal observation that the smell coming from burning

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255 张天华: 浅议西藏牧区能源与草地生态环境的关系 Relations between Energy Resources and Grassland Eco-Environment in Pastoral Areas of Tibet 环境保护, Environmental Protection, 2001 (2)
yak dung is more or less like herbal medicine, it seems probable that there is not much nitrogen, phosphorus and potassium inside the dung. This conjecture gets validation from recent research:

The total quantities of NO$_3^-$-N, NH$_4^+$-N, available K and inorganic P from the initial dung largely decreased to almost none after 84 days. In the initial days (1~9 d), NO$_3^-$-N, NH$_4^+$-N, available K and inorganic P in soil under the dung piles were found with a significant increase, and after two months the content of NO$_3^-$-N was 8.4 times larger than that in the initial days. The contents of NH$_4^+$-N, available K and inorganic P at place 10 cm from the edge of dung piles increased significantly (P<0.05), but no significant increase was found (P>0.05) at 30 cm. Differing from the common belief, no obvious increases in organic C, total N and total P were observed in the whole experiment process.  

Coincidentally, yak dung in China's Tibetan areas is seen as a fuel to be used rationally and efficiently, while on the other hand Australia once had serious fecal harm issues from cattle dung. Australia is a country of a myriad of luxuriant grasslands. From the 18th century, European immigrants introduced a large number of cattle and other livestock. The superior natural conditions supported the development of husbandry. But, because the cattle dung was not treated effectively, a growing quantity of dung covered the developing grasslands causing a serious impediment to the growth of grass. So many blocks of bare patches appeared in the gradually degraded grassland.  

Although Australia has several hundred species of native dung beetles that make use of the fibrous dung produced by kangaroos, wallabies, wombats and other native mammals, they are unable to cope with the large quantities of dung produced by introduced livestock. So, the government allowed scientists to introduce more than 50 species of dung beetles to Australia from Europe and Africa to deal with the dung problem.  

6-4 Historical Aspects of the BYHT  

6-4-1 The BYHT in ancient Chinese documents  

Historical records of the earliest black tent can be found in the ancient Chinese book, *The Biography of Periphery of the Uncivilized Ethnic Groups of the Book of Jin* published in AD 648. It stated that the Qiang (the ancestors of Tibetan) people were, “…following up and chasing after the water and grass; living in a black tent and eating the meat and cream as the food.”

During the Jin Dynasty, in the sixth century AD, a tribal chief called Rangri Lunzan (AD 570-620) attempted a merger with neighbouring tribes by force of arms. Later, his son, Songtsan Gampo (AD 620-649) completed this mission. At the beginning of 7th century, Songtsan conquered and merged some ancient Qiang tribes, and around AD 632 built a strong Tubo Dynasty with a capital in Luósuò, which is the Lhasa of today. In Songtsan’s heyday he commanded various tribes of the Qinghai-Tibet Plateau and his influence was far reaching to the Western Regions and Helong Area. After the 9th century the Tubo Empire disintegrated and changes occurred. The Yuan Dynasty was established and the region under Tubo was included in the territory of the Yuan Dynasty domain. Gradually Tubo (Tufan) became substituted by Tibet as the name of the race.

After an alliance through marriage by which the Princess Wen Cheng was sent in AD641 by Emperor Taitsung of the Tang Dynasty to marry Songtsan, the relationship between Tang and Tubo had a honeymoon period until AD 670. From then on to the year of the end of Tang in AD 907, there was a long war between Tang and Tubo who were locked in a titanic struggle for the controlling power of the Helong Area and Western Region. The characteristics of this wartime period were alternating periods of fighting and peace, like a seesaw battle. During the war the two sides reached great strength; Tang’s soldiers reached 180,000 in number in AD 678 and Tubo’s 400,000 in AD 670. A great number of tents were used for dwellings for such large-scale field troops. There are a number of descriptions especially of Tubo’s tents in the historical and literary Tang writings. *Fulu* (拂廬) in Chinese refers to tents occupied by the upper class Tubo people at that time. One of the greatest poets, Du Fu, who wrote (translated) See Judge Young Lu off to West Tubo for diplomatic mission said that “…lush

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259 The Jin Dynasty (A.D. 266 -420) was one of the dynasties in Chinese ancient history. Book of Jin《晋书》 is a systematic, complete history book of the Jin dynasty.


261 Helong Area, loosely speaking, was today’s Gansu and Ningxia provinces. There is varied topography, in addition to its location of connecting East, West, North and South. From ancient times to now, the region here is full of many complex ethnic and economic patterns and colorful culture.

262 In mainland China, most historians, the Modern Chinese Dictionary, and historical textbooks generally give ancient Tibet as Tübö; and some mainland China, Taiwan and Western scholars give it as "Tüfän". But, the Japanese give Tibet as Toban.
grasslands foster strong Tubo horses, the heavy snow covers the ground but the Fulu is dry.”\textsuperscript{263} Fulu was mentioned in the Biography of Tubo (Part I) of the Old Book of Tang (《旧唐书・吐蕃传上》), “The honoured persons are living in the big felt tent which is called Fulu.”\textsuperscript{264} In the early years of the Tang Dynasty, envoys from Tubo brought tribute to the Tang Dynasty court. Such scenarios were described in the Record of Gaozong\textsuperscript{265} (Part I) of the Old Book of Tang (《旧唐书・高宗纪上》), “…Tubo’s imperial envoy dedicated a hundred horses and the big Fulu whose height can be 5 Zhang and both length and breadth are 27 steps each.”\textsuperscript{266} This book gave the Fulu’s three dimensional sizes. Furthermore, the details of the Fulu’s campus and scale were reported in the Biography of Tubo (Part I) of the New Book of the Tang Dynasty (《新唐书・吐蕃传上》) which later stated, “Tsanpo (Tibetan King)...also had a house in the city but he didn’t want to live there, he liked to live in the big Fulu composed of several tents, which can house as many as several hundred people, while his solders lived in small Fulas.” All of these descriptions explained that the Tubo people liked to live in a Fulu rather than a house. Tent living was a practice, custom, or even belief, shared by the Tubo people as part of their common culture. This is a time-honored custom.

6-4-2 The Fulu was not a felt tent

Although there is not enough proof to say that the Fulu was the equivalent of the BYHT, based on the above analysis and review of China’s ancient documents, at least the ancient Fulu can be said to be a prototype of the BYHT. However, this does need some clarification. The term Fulu was widely used in ancient Chinese historical books as mentioned before, but in some of them Fulu was identified as or misunderstood to be a felt tent, which is not right. This is because the felt was made from animal hair, mainly from sheep, camel and yak. After its physical processing such as wetting, heating, extrusion pressing and so on, the felt created was made of laminated non-woven fabric. This process means that felt cannot stand repeated folding and can only be transported and stored in a rolled up state. So, felt is primarily the material for the yurt, which is made by placing the felt layers on a skeleton framing around a central wooden pole, and is mainly used by the Mongolians. In contrast, the typical black tent in Tibet is made from the undercoats of the yak through twisting, spinning and weaving them into a number of catty width brown strips which are called Pulu. After sewing many strips together the tent

\textsuperscript{263} Text proper in Chinese: 杜甫《送杨六判官使西蕃》诗: “…草肥蕃马肥, 雪重拂庐乾.”

\textsuperscript{264} Text proper in Chinese: 贵人处於大毡帐, 名为拂庐.

\textsuperscript{265} Gaozong Li, Zhi (AD 628 – AD 683), the ninth son of Emperor Taizong Li, Shimin, ascended the throne in Zhenga in AD 649 and died in AD 683.

\textsuperscript{266} Text proper in Chinese: 吐蕃使人献马百匹及大拂庐可高五丈, 广袤各二十七步, 丈 Zhang = 3.07m in the Tang Dynasty.
cloth is made (for further details see section 6-3-4). The cloth of the black tent must be good at resisting creasing because of its high frequency of moving. So, Fulu should not be used to mean a felt tent. This error came because of the limitations of both the Old Book of Tang and the New Book of Tang. The chief editors of both books were politicians instead of scientists. Fulu is very likely a slip of tongue or misunderstanding of Pulu. However some people today still mistakenly interpret the meaning of this word. A recent on-line book\textsuperscript{267} takes Fulu as a Tibetan word meaning felt tent. In fact the black yak hair tent is called sbra-nag, the white wool tent is sbra-dkar and the cloth tent is ras-gur in Tibetan. Another research paper published in 2007\textsuperscript{268} regarding the pictures contained in two wooden coffins of the Tubo dynasty unearthed in the Haixi prefecture of Qinghai province, pointed at some circular tents more or less in the style of the Western Regions saying these are the Fulus which were mentioned in the Biography of Tubo (Part I) of the Old Book of Tang, although this Book clearly stated that the Fulu was square because “both length and breadth are 27 steps each.”

6-4-3 Religious uses of the BYHT

Without going to Tibet it is very difficult to imagine how the Tibetan Bodhisattva is so closely related with every level of Tibetan life. In the sixteenth century, a nomadic tribe went through many places eventually arriving in North Tibet's Qiangtang prairie from the distant grasslands of Qinghai Yushu. The name of this tribe was Baier (Pinyin). After settlement, they erected tents, herded sheep, but also built a tent temple for the worship of the Buddha, which was called Baiergongba (柏尔贡巴). Gonpa is temple in Tibetan. The tent temple offered mobility to the nomadic people for the reciting and chanting of the scriptures and for running dharmic commentaries, therefore, it is also called Baiergaqin.

Baiergongba is the only sizable tent temple which has been well preserved in the whole of Tibet. Its big Scripture Hall, the Buddha Palace, the monks’ accommodation and so on were made up from all kinds of tents. Baiergongba’s layout is the same as that of other Tibetan temples: there is the big scripture hall in the front part for the clergy where they assemble and chant sutras; the Buddha palace of Bodhisattva is in the rear; and the monks’ accommodation is around. The big scripture hall was made of Pulu from black yak hair by stitching the pieces together with the cloth supported by 80

\textsuperscript{267} Text proper in Chinese: 程娟, 现代汉语语音及词汇讲义, 北京语言大学. Cheng, J. Modern Chinese Phonetics and Vocabulary (Chinese Handouts), Beijing Language University, Beijing, China.

\textsuperscript{268} Xu, X. (2007), A Trial Discussion on the Wooden Pictures’ Origins of the Coffins During the Tubo, Journal of the Qinghai Nationalities Institute (Social Sciences), Vol.33 (1) Jan. 2007, Xining, Qinghai, China
wooden poles inside. It can simultaneously hold 200 people to assemble the sutras. A Buddha Palace's tent was a round fort-style tent, somewhat similar to the yurt. Inside and outside were of natural woven cloth with felt in between, supported on wooden sticks. Many such tents for Buddha were placed to the rear of the big scripture hall tent, thus forming a large tent set inside many small tents. The monk accommodation is in small tents which vary by quality of material and size. Generally they are brought by the Buddhist monks from their families. One monk can live in a tent or some 2-3 people live together in a tent, depending on the family conditions. In Baiergongba’s most prosperous time, the Buddhist priests reached more than 200 in number. There were over a hundred monk tents which were distributed around the main black tent, making a very spectacular scene.

According to historical records, Nagqu prefecture has 109 temples of all kinds, including quite a number initially constructed in the form of a simple tent temple. For example, the Xiao Deng Temple in Nagqu, founded in the early eighteenth century, began as a tent temple. At first several Lamas who went to study in Lhasa’s Sera Monastery returned to Nagqu to carry on their religious activities every summer, but suffered from the lack of a temple in the locality. As a result, they manufactured several tents in Nagqu to house a scripture hall and the monk accommodation, gradually forming one small temple which was called Xiaerba. In Tibetan, Xiaerba means ‘erecting a tent to live in the wild.’ Afterward, along with the economic and cultural development, it was gradually converted into a wood and stone structure. In 1814 it was expanded into a 12 pillar scripture hall, then in 1842 expanded again to a 48 column three-floor scripture hall and more than 100 accommodation units were built. Step by step, Xiao Deng Temple has been constructed into the most famous temple in Northern Tibet.

6-5 The Main Areas of Distribution for the BYHT
As one of five pastoral areas, Changtang is not only a paradise for wildlife, but also has a rich fertile soil for pastoral culture. On that vast prairie, one can easily find scattered herders of yaks and sheep together with their black tents. The term of Changtang in North Tibet is a cross-regional name with a Tibetan meaning of Northern Plains, and refers to a vast plateau surrounded by many mountains such as Nyainqentanglha Hill, Gangdese, Tanggula, Kunlun and the Hoh Xil mountains. The range broadly includes most of the northwest Nagqu Prefecture (the five counties of Nagqu, Amdo, Bangor, Xainza

269 Compiled by Cultural and Historical Data Room of Tibet Political Consultative Conference of Nagqu Prefecture (1995), Strange and Beautiful Scenery, Unique Resources (Tibetan), Lhasa: Tibet People’s Publishing House
and Nima), the east of Ngari Prefecture, the small division of northern Shigatse, Damxung County of Lhasa, and a small division of southwest Qinghai Province.

Covering more than 700,000 square kilometres which is bigger than the size of Germany, Changtang’s territory is the main part of the Qinghai-Tibet Plateau and consists mainly of steppe and grasslands, although alpine deserts, scrub forests, bogs, and geothermal zones are also found. Changtang includes the north-west of Tibet, and southern Xinjiang and western Qinghai Province. Average elevation is above 5,000 metres, and there are more than 60 peaks with elevation above 6,000 metres. There are a series of plateau lake basins, but the majority are saltwater lakes. Vegetation cover is sparse and low. Especially in the north, the climate is cold, with an annual average temperature below zero, and a lowest temperature of minus 40°C. There are many gales, and snow is possible even during the summer months. The Tibetan herdsmen have lived in southern Changtang for more than a thousand years. Because the ecological environment is severe, most districts of Changtang are desolate, uninhabited land. It is possible to plant the spring Tibetan barley below an elevation of 4600 metres in areas with a different microclimate environment; other areas are the nomadic regions. In the last 50 years, some partial herdsmen have migrated to the north and settled down there, but on the whole, the northern part of Changtang is still an unpopulated area until the present. While this is by no means a regular rule, these uninhabited lands can be entered either by the many tribes who permanently moved there in 1970s or by sporadic herdsmen temporarily migrating there with their cattle in their search for fresh grass.

Over the past 100 years, few western explorers have passed through this mostly unpopulated area. Sometimes the explorers encountered pastoralists, hunters and a very few bandits, but these were seasonal activities as there were no year round settlement of villages and herdsman. More than 100 year ago the unpopulated areas were much bigger and the primary cause for this is that, with the development of animal husbandry, the herdsmen of southern Changtang have expanded their grazing area toward the north and many herdsmen have started to settle in the northern region. Prior to this modern development, the black tent played an unrivalled role in herdsmen’s activities such as grazing.

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and hunting in this uninhabited land. Because Changtang is dominated by animal husbandry, unlike many other nomadic groups the Chanting people are not under pressure from settled farmers as the vast majority of land they inhabit is too inhospitable for farming. 271 Best suited to the nomadic way of life, the movable tent has no competitors. So traditionally the basic habitat forms in the area are based on tent living.

The town of Nagqu (Chinese: 那曲) as part of the most important pastoral region in North Tibet is generally considered the centre of Changtang, as well as the livestock product collection and distribution centre and the important transport hub in North Tibet. It is located more than three hundred kilometres away from Lhasa. There are six prefectures in the Tibetan Autonomous Region (TAR) but only Nagqu Prefecture is a purely pastoral region where black yak hair tents (BYHT) are the prevalent living forms for the herdsmen. According to the Tibetan lunar calendar, summer is the shortest season of the year, and there is no real summer in this alpine region. For celebrating such a precious time of year, promoting tourist business, and as part of religious beliefs, local governments organise all kind of festivals, including horse racing, and other activities at this time. Some nomadic people living in outlying areas travel tremendous distances to attend these week-long festivities. They bring along their families and erect tents along the sites of the organised horse and even yak races. In their temporary homes, the herdsmen spend a week or so enjoying the sports and entertainments, Tibetan barleywine, and trading or exchanging their pastoral products after a year’s hard work. The hundreds of colourful tents gathered together make a charming pastoral scene on the plateau. So Changtang in summer served as the best place for investigating the BYHT for this thesis. Also in the Tibetan summer, there is maximum oxygen content in the air 272 and less altitude stress and this adds to the overall sense of well-being.

On the North Tibet Plateau grazing land changes all the time and lacks wood, so traditionally there is almost no practice of living in a permanent houses. Not only do the herdsmen live in tents, but also the people who have power and privilege. The tribal chief of Hall 39 Races 273 lived in a big tent which

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272 Source: China Tibet Information Center

273 Hall (Hur or Hor) is also known as Kham. Hall 39 Races plus 40 adjacent races, at that time collectively the whole was known as the 79 races. According to the "Annals of Guardian Tibet" (circa 1795), Hall 39 Races were scattered in the “Tubo, the home of Sichuan, Tibet and Xining between the three realm sections.” At the end of the Ming Dynasty, the area was ruled by the Mongolian tribes. They
could accommodate ten thousand people (really? That’s a lot of people for a plateau with low population density). Later, the beneficiary of this tribal chief interpreted the place name as today’s Baqen (Tibetan meaning of big yak hair tent). There are a total of 162 administrative villages in Baqen County, and 37 are not accessible by road. The main economy is based on animal husbandry, as cropping is a very small part. The average elevation is 4500 metres above sea level. There are nearly 4000 tents in Baqen County today with a population of 40,000, and among them the traditional yak hair tent accounts for 30% of the total. Currently, Baqen County has many tent stores, some tent teahouses, and tent hotels along state highway 317. These tents have greatly facilitated the productive life of the populace, and contribute to the considerable tourist income.

Known as the “pearl of northern Tibet” Damxung (当雄) has the meaning of “a good chosen place” in the Tibetan language. It is one of the best grass pastures for sheep and yak in the Changtang prairie and the only pure animal husbandry county in Lhasa City. Tent living is still quite popular there.

Though there are fewer and fewer yak wool tents each year in Tibet, there are still a few areas that have considerable numbers, including the Ngari (Chinese:阿里) prefectures in the west of Tibet Autonomous Region. Under its jurisdiction of seven counties, three counties are pure pastoral areas, and four counties are half-farming and half-grazing area.

It can be basically predetermined that the distribution of black tents is parallel to the area of yak husbandry in Tibetan inhabited areas beyond the Tibetan Autonomous Region (TAR). In Qinghai Province, the BYHT is distributed mainly over all 12 counties of both Guoluo and Yushu Tibetan Autonomous Prefectures (果洛藏族自治州和玉树藏族自治州), Zekog County (泽库县) of Huangna Tibetan Autonomous Prefecture, Tianjun county (天峻县) and the countryside of Geermu (格尔木) City of Heisey Mongolian and Tibetan Autonomous Prefecture, Qilian County (祁连县) of Haibei Tibetan Autonomous Prefecture and the pastoral area of Xinghai County (兴海县) of Hainan Tibetan Autonomous Prefecture. There are some exceptions such as Henan Mongolian Autonomous County, which although noted for being an area of yak husbandry, is inhabited by Mongolian people who prefer to live in the yurt. In Sichuan Province, the BYHT is mainly located in counties like
Serthar (色达), Litang (理塘), Dege (德格), Shiqu (石渠), and Baiyu (白玉) within the northeast Ganzi Tibetan Autonomous Prefecture (甘孜藏族自治州), and Hongyuan (红原), and Zamtang (壤塘), Aba (阿坝) and Zoige (若尔盖) Counties in Aba Tibetan Autonomous Prefecture (四川省阿坝藏族自治州). In Gansu Province, distribution is mainly concentrated in the area of Gannan Tibetan Autonomous Prefecture (甘南藏族自治州) which consists of Hezuo city (合作市), Xiahe (夏河), Luqu (碌曲), Maqu (玛曲), Lintan (临潭), Choni (卓尼), Diebu (迭部), and Zhouqu (舟曲) counties, plus Tianzhu (天祝) and Sunan (肃南) which are two animal husbandry counties. In Sichuan Province, the BYHT is mainly scattered in Deqing (德钦) County of the Diqing Tibetan Autonomous Prefecture (迪庆藏族自治州).

There are also small BYHT areas around Mountain Everest in Nepal, Bhutan and India among the Tibetan-speaking nomads living there. However hand woven yak wool tents are gradually disappearing. Many nomads now only live in these tents in the summer months for leisure, living in mud-brick homes the rest of the year. Others are moving into towns to live in traditional style Tibetan homes or are being relocated into cities (such as Xining) where the government gives them a modern style apartment.

6-6 Tibetan Herdsmen's Life Styles

Tibetan nomads are usually called by the name of Drokpa, meaning people of the solitude or nomadic pastoralists and they are truly a mountain people, having herded livestock on the high altitude pastures for millennia. They live a holistic lifestyle in harmony with nature and the seasons, and one which has remained unchanged over centuries, thus making them the repository of original Tibetan culture. Tibetan nomads are easily identifiable by their wind-burned cheeks and thick fur coats (Chuba). They use the coats for wear in day time and as a blanket when sleeping on their nomadic trips in search of grazing. Chubas differ across Tibet. In Lhasa they are very thin and are rarely lined with wool, while in the nomadic areas they are very thick with long sleeves and are always lined with many sheep skins. The sleeves on these coats are overly long, usually extending down to the knee, and have multi-purpose uses, such as for storage of small objects, for making bargains by using sign language inside the sleeves for some special trading, and in Guozhuang even for dancing as mentioned before. This dancing is prevalent in herding and half-farming, half-herding areas and its movements usually come from the extremely long sleeves dragging on the ground and then being flung up and down. Hats made from fox fur are worn by most nomads along with boots made from yak hide and lined with fur. These boots come up high on the leg to just below the knee. A long, sharp knife can be found on the
side of every nomad. Tibetans cut towards themselves, not away from themselves as most people in the West are taught. Amulets or pictures of some Buddhist figures are worn around their necks along with many strings of prayer beads.

Tents are normally the nomads’ chief possessions, because their other possessions are few. The tents of the nomads are easy to put up and take down. To pitch a tent, people first use sticks to make a frame as high as two metres, and then cover it with black yak Pulu cloth, leaving a gap at the middle with a 15cm width and 1.5m length. This split will let smoke out and sun light in. Finally, the four sides of the tent will be secured to the ground with yak wool ropes. All in all, it is easy to pitch a tent because of its simple structure; meaning it is also not difficult to dismantle it for travelling. When a family is ready to move to a new pasture, the tents are rolled up and packed onto yaks. After dismantling a small family tent of around 18 square metres the two pieces of tent can be packed to the same dimensions as two pieces of air luggage (a 24 inch rectangle) which can be carried by a yak. For some oversized tents, special arrangements have to be made before starting a long distance move. Pre-arrangements including tailor-making the tent cloths as each piece will be made according to the yak’s carrying ability of up to 150 pounds of load. In addition, some special carrying frames will be designed which decrease the strain of carrying on the yak, enabling the animal to transport for a long time over long distances. Of course a yak fleet will be needed when moving a big tent of more than 150 square metres.

In the summer months it is common for Tibetans to live in white, canvas tents. These tents often have one or more of the eight auspicious symbols on them. These canvas tents are also used during horse racing festivals. White tents were formerly used by wealthier people for picnics, or as a place to stay during summer festivals. Nomads will often live with members of their extended family. Usually the tents of the nomads are in groups of two or three, though sometimes they are alone. Nomads live far from towns and villages and have little modern technology in their lives, and their children do not usually go to school because of the long distance to the nearest available one. In some areas, nomadic life has changed little over the past 500 years.

As the original tent technology spread it was adapted to fit each environment. In mountains where there is some rainfall, the roof was steeply pitched to shed rain. In the desert it was flattened and lowered to shield its inhabitants from the sun and sandstorms. The Himalayan terrain is one of the
harshest on Earth and its inhabitants have displayed incredible ingenuity in adapting to that environment, sheltered by their woven yak-hair tents which last for 15-20 years and whose fibres swell to keep out the rain. In contrast the modern synthetic tents let in the cold air and have to be replaced every two to three years.

Inside the tent, people will build a 50cm high wall which is made of grass-earth-brick, earth brick or stones, on which barley, butter bag or yak dung (fuel) are usually placed. The tent is poorly furnished. At the middle (near the door) of the tent, an earth fireplace is set up, and behind is a shrine equipped with a statue of Buddha. People often spread a sheepskin rug on the floor for rest or sleep. Nomads do not sleep in beds, but on sleeping mats, whose sizes are little more than big rugs. They keep warm using blankets and sheep skins. Outside prayer flags can usually be found strung up on the tents and it is also common for the nomads’ tents to have idols and images of Buddha inside.

Nomads keep their yaks in line using a tether made of woven yak hair. It is quite usual for boys as young as seven to be seen herding yaks on their own, and the older men (probably their family members) will bring a bottle of milk tea or butter tea with them when they head out to graze their yaks. Women and children go out every morning and collect the yak dung to be dried.

6-7  The BYHT- Why This Tradition must be Retained

The Tibetan black tent is both part of a unique cultural landscape and a system for sustainable living. It has allowed people to make a living from the very tough natural conditions characterized by very high altitude, cold climate, very thin air and remote location.

The BYHT has a long tradition and has remained unchanged for many years. It is a sustainable form of man-made living environment that is only just starting to disappear. The culture of the people is bound up with how it is possible to live in the harsh environment using the BYHT.

The residents here mainly depend on animal husbandry, and the Tibetan tribes had identical modes of nomadic production, which for generations meant migrating to wherever water and grass were available. Through thousands of years of productive labour practices, the herdsmen on the Qinghai-Tibet Plateau have accumulated rich experience in both production and life which enable them to live harmoniously with the natural environment. The pastoralists generally used different
forage options in different seasons, depending on the different geographical locations and forage species for feeding different livestock, so the ecology reached a basic equilibrium. But in the past these people knew they were subservient to nature and passively accepted what nature in terms of the harsh climate threw at them. The Tibetans adapted to this natural environment to the extent that they worship the mountains and lakes in Tibet as holy objects. From the 1980s, the reform and the open policy of central government have enabled the herdsmen's ideas to change considerably. The structures of production and life have changed gradually, and the main new characteristic is the appearance of herdsmen's settlements that have caused the traditional nomadic way of life to be switched into a settled or semi-nomadic life. Without doubt it has improved the herdsmen's living environment and conditions, but only when they are judged by modern global standards.

Another change has been the development of local ecological problems. These include glacial recession, grassland desertification, and damage from an increasing rat population. All of these issues are interconnected, as shown below.

These phenomena come out of the changing ideas of traditional ecology and the style of production and life, as well as from certain mistaken aspects of government policy. These were mainly manifested between 1970 and 1980. During this period the quest for an increased number of livestock, in addition to the growing population of the pastoral area, caused over-grazing and neglected the relationship between the environment and development, population and natural resources. For example the number of domestic animals in Maqin County of the Guoluo Tibetan Autonomous Prefecture increased from 227,202 in 1958 into 600,126 in 1995. The normal ratio of pasture land per sheep should be 12 Mu but presently the average land for each sheep is only 5 to 9 Mus. Too many domestic animals have used the limited pasture for too long. Moreover since the beginning of the 1980s, after the selling of domestic animals to each household and the establishment of winter settlements, the herdsmen would graze their animals in the same pasture for a long time. This has caused damage to the pasture resulting in the increasing desertification of the grassland. Also soil erosion has taken away fertility and destroyed the ability of the grassland and shrub cover to regenerate. But these are not the only reasons for the recent problems. Due to the drive for an improved economy, since the mid-1980s

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277 Mu (unit of area) (亩 or 畝) is a Chinese unit of area. A hectare is equal to 15 Mu.
a large number of herdsmen have killed foxes, wolves, otters, sand foxes, weasels and other natural enemies of the rat. The resulting rat damage has caused further desertification of the pasture, leading to one misfortune after another.

These changes to the ecological environment have also caused a change in the production methods of the Tibetan people generally. Because the pasture is the main resource underpinning the herdsman's livelihood, both the degeneration of pasture and the loss of balance in the local ecology have caused the number of animals to decline, to the point where they can no longer satisfy the herdsmen’s needs for production and life. For instance according to normal practice, 9 cows per capita are the livestock requirements of a middle-income family. However, as a result of the ecological degeneration, a person can now only have 5 cows. This means a drop in living standard, which in turn influences the quality of life.

Facing an unoptimistic ecological situation, the government has implemented a policy of banning grazing and delaying grazing on the prairie that has been badly degraded. During the period of the ban the cattle and sheep must be enclosed in feedlots. This policy certainly reduces grazing and appears to be significantly reducing damage to the grassland, but the problem is that keeping livestock in captivity is in violation of the animals’ natural disposition and makes it easy for illness to occur and spread, which in turn reduces livestock breeding and growth rates. Moreover, captivity requires massive amounts of feedstock to be brought in. The cost of purchasing cut grass is extremely high, and the herdsmen simply cannot afford to do this.

Reduction in livestock numbers looks as if it should lead to an improved environment. However, this may not be true. Several ecologists have studied the problem through field testing under the condition of an absolute ban on grazing to see whether the prairie ecology will be improved. They observed the Sino-Mongolian border which is a completely fenced area, finally finding the grassland had been completely destroyed. In contrast, another ecological research project proved that the moderate trampling of ungulates can break the hard shell of crust on the soil surface in the dry season and loosen the soil surface, thus improving the aeration of soil. Trampling also helps the plant seeds

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279 田裕钊：非洲大陆萨赫勒地区的沙尘暴由于人为原因而加剧(Tian, Y. Z., *The sandstorm in areas of African Sahel intensify as a result of the artificial reason,* www.unccd.int/publicinfo/duststorms/part3-chi.pdf)
buried in the soil by covering them with soil which plays a role like seeding. A moderate intake of young leaves and shoots as a result of grazing can clear away excess biomass, so vegetation is sparse and not dense, which helps to speed up the fixing of carbon dioxide and slow the degree of transpiration. Livestock is both the consumer and a link in this ecological system. Even without considering yak dung most livestock excretions and urine are part of the return of nutrients to the soil, which is not only beneficial to its enrichment with both the primary and micro nutrients required for plant growth but also helps in the formation of plant litter.

Obviously, the prairie ecology is a complex system but it seems that both banning grazing and over-grazing on the prairie can equally damage the prairie environment. The reason lies in the fact the existence of the prairie depends on a complete ecological chain, of which the herbivore is an indispensable part. Nomadic grazing is a cheaper way of using the natural resources as the biggest input is the labour to take care of the animals on the rangeland. Yet under the new conditions when the animal population has doubled and has thus exceeded the limit of natural vegetation restoration, the issue of over-grazing will need to be addressed. So, the best solution to save the current ecological crisis of the prairie grassland could be a return to moderate levels of nomadic grazing.

Essentially nomadic grazing means the nomads roam through the alpine pastures in pursuit of the best rangeland and water to feed their livestock instead of keeping them in one place. Nomadic grazing and rotational grazing are not the same; the former is a large-scale shift in the field and latter is organized on an area basis. The key to nomadic culture is mobility. One research study pointed out that nomadic ecological theory is implied in the functional relation between the health status of the grassland and the grazing radius. The health of the grass can only be maintained through extending the radius of nomadic grazing.

According to some investigations during the Republican period the Tibetan and Mongolian families living in the regions of Gansu and Qinghai were similar to the prairie nationalities, but had a

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280 Primary nutrients refers to the large number of elements such as C, H, O, N, P, S, K, Ca, Mg and micro elements that is Fe, Mn, Zn, B, Cu, Mo, Cl, Ni, etc.

281 达林太：蒙古高原生态脆弱性与人地关系, 内蒙古楚日雅牧区生态研究中心, 呼和浩特, Darling Tai, The ecological fragility of Mongolian Plateau and relations between people and land, Churiya Research Centre of Pastoral Ecology, Hohhot, Inner Mongolia

282 满洲国兴安局：兴安西省阿鲁科尔沁旗实态调查报告书，康德八年，第 64-66 页 Xingan bureau of Manchuria regime, The investigation report of reality condition in Arhorchin Banner of West Xingan Province, 1941, pp. 64-66
different social family organization. As a result, their ease of movement was not the same. The Tibetan tent appears coarse in terms of its organization. It is erected simply, the weight is really light, and the volume is also small, therefore it is ideal for migration. The Mongolian yurt is not like this. Its organization is complex, it is erected from numerous and diverse parts, the quality is very heavy and the volume is also big, so it is not advantageous for migration. Therefore to facilitate the movement of the family, the Mongolian tent is inferior to that of the Tibetan. The nomadic Tibetans will move in search of new pasture before the forage grass is completely eaten, moving with only a couple of yaks and houses. Because Tibetans carry all their household wares as they move, the consumed grass restores quickly, in contrast to the Mongolian way of life. The migration of the Mongolian entails use of a significant number of camels or horses and cattle, and their family structure is very complex and difficult to move, so there is almost no grass to graze around Mongolian dwelling settlements, leading to the condition of over-grazing. Since the migration is directly related to the ecological environment of the grassland as well as to the rate of livestock breeding, in terms of nomadic grazing, the right of travel is more important than the right of residence. The stronger the mobility, the more advantageous it is for maintaining the ecological environment and the growth of domestic animals in the prairie. From this point of view, the BYHT is a product of compromise between the Tibetan herdsmen and the harsh environment which offers a possibility of existence in the Alpine pastures. So as long as there is Tibetan grassland there will be the BYHT, even though it is not supported by government policy.

6-8 Recent Development of the BYHT on the Plateau

Starting from 2006, the Tibetan Autonomous Region (TAR) government has carried out a housing project which was called “Comfortable Housing.” The implementation of the project is to allow more herdsmen to switch from nomadic living into semi settlement. It has profoundly changed the way of living of the Tibetan peasants and herdsmen. From this has emerged problems of separation between the herdsmen and their animals in some parts of the pastoral area where once the traditional tent had been their home with the people and livestock living together. After the herdsmen voluntarily moved into their low cost housing, it was found that there were considerable distances from the settlement to winter pasture points, making for a tough lifestyle. As a result, some of the herdsmen graze their animals nearby, which is causing over grazing and serious grassland desertification in some places.

Generally the Tibetans of today more often live permanently in one place rather than following their nomadic tradition. As a result, hand woven yak wool tents are gradually disappearing. Many nomads
now only live in these tents in the summer months, as when the herders are away grazing tents may be chosen for group living. They live in mud-brick homes the rest of the year. Others are moving into towns to live in traditional style Tibetan homes or into cities like Xining where they live in modern government apartments. Sadly, there are fewer master craftsmen and also insufficient written records regarding the making of the black yak hair tent. For whatever reason, the black yak hair tent is now less important as part of a traditional way of living and its place in a relatively primitive eco-balance is being challenged. However, with a reduced residential function, the commercial function of tents is under development.

Currently, there are a growing number of tent campuses in Changtang. Many of these contain tent stores, tent teahouses, and tent hotels usually along the rural roads and even state highways. These tents have facilitated the productive life of the populace to a great extent, as they contribute a considerable tourist income. Fortunately, the black yak hair tent as part of a unique Tibetan way of living is being redeveloped for this booming tourist industry. The following three case studies can better illustrate this tendency.

![Fig.6-2](left),a typical residential black yak hair tent from Baqen. Fig.6-3 (middle),a traditional support node.Fig.6-4 (right), three rows of double T frames

### 6-8-1 A Residential Black Yak Hair Tent from Baqen

This demonstration tent is a typical residential black yak hair tent (Fig.6-2) from Baqen (“Big yak hair tent” in Tibetan) County. According to Tibetan customs, black tents do not have any added decoration, but all over the pillars at the front of the tent colored sutra streamers are hung for good luck and happiness. Prayer flags can usually be found strung up outside the nomadic tents. Regardless of where the tents are, the herdsmen will not forget to hang up these colored strings on the tent's connecting ropes with the hope that luck will follow.
This demonstration tent was considered the most authentic black yak hair tent at the Horse Racing Festival in Changtang in 2009, because its form, materials and technology strictly observe Tibetan traditional craftsmanship. Following the traditional process, this tent's structure adopted a double T-shape frame. The traditional support node where a ridge column meets a ridge beam (Fig.6-3) as used in this black tent is made out of timber and yak hair and usually incorporates a yak knuckle bone or similar joint. As well as adding an aesthetic appreciation of Tibetan tradition, which is the worship of the yak and its strength, this kind of joint is absolutely in line with the modern principles of a mobile and rapidly assembled structure as it is simplified for fabrication and erection. The structural characteristics of the demonstration tent are as follows:

a) Although the tent area is only 64 square metres, three rows of double T frames (Fig.6-4) take the place of the single double T frame of a small tent.

b) Because the three rows of double T frames offer enough inside support to the tent cloth, there are fewer outside stakes and tension ropes than for a tent with only one double T frame.

6-8-2 Tent temple of Arou Big Temple

This tent (Fig.6-5) is located in Qilian County, Haibei Tibetan Autonomous Prefecture in Qinghai Province. Arou Big Temple (阿柔大寺) is the largest monastery of the Arou tribe in the Qilian Mountains area, and was built in the middle of the 18th century AD. It was originally located under the snow-capped Anyemaqen Mountains where today’s Guoluo Prefecture is and in 1822 moved with the tribe northbound to Qilian, initially without a fixed temple site. After the tribe’s relocation was completed the temple members started to build a tent temple at the current location. Before 1958, the entire temple had 5 halls, 840 adobe houses, and 7 giant yak hair tents and yurts that served as the scripture hall and the hall for worshipping Buddha. After 1958, many buildings were demolished and the reduced site was reopened in 1962. In 1966 it was closed once more and

283 From conversation with Mr. Reda of the Tourism Administration of Nagque Prefecture.
some of the buildings were again demolished due to the political chaos. It eventually reopened on November 20th, 1980. The existing black yak tent at the Arou Big Temple covers 1189 square metres; its internal building area is 300 square metres, and it has a height of 4 metres, and 34 columns. The whole tent uses nearly 1,000 kg of yak hair and 2,500 metres of rope. According to local knowledge, this giant tent was sewn in October 2006 by 50 people working together. The Executive Vice-chairman Sonam Dorje, of the Qinghai Folk Literature and Art Association, said that the tent structure is a unique mode of temple construction for the local nomadic religions. According to some people, Arou Big Temple’s historic tents were even larger than the new tent. In the past more than thirty yaks, each fully loaded with Tibetan scriptures and ritual implements, could directly enter the tent at one-time.

Compared with other Tibetan Buddhist temples Arou Big Temple is not very large, but the whole building complex is well organized and although scattered it looks simple and elegant. It is a combination of both Tibetan and Chinese architectural forms. Its tent part was produced using a very high level of technology. Both craftsmanship and structure basically follow the traditional principles of the residential black tent system. There are four details of the structure worthy of noting separately.

a) Underneath the ridge pole, a drum-like stone column base (above right) was used for support. This feature was previously only used for palaces or important buildings and mostly by the Han nationality.

b) Creatively adopting the “X” shape, cross linking ropes underneath the inside of the roof made from black yak felt tying the four corners of the large piece of felt improves both the deformation of the structure and sag of the roof felt. This method is not seen in residential tents.

c) There is a pile hoop made from metal sheet at the top end of the ridge pole at the junction point between the ridge beam and pole. Traditionally a knuckle bone or similar joint without any bone would be put there, which is satisfactory for a residential tent of up to 30-40 square metres. However, Arou Big Temple is the largest tent temple with ten times the floor area. Because of the heavy load from the whole roof, rain and snow, the top end would easily be worn around the pole without the reinforcement.

d) The internal support structure is made of one double T frame that is two ridge columns plus a ridge beam, as in a small tent. By doing so, there are only two columns existing in the space of 300 square metres, which is extremely compact and material saving. Its external system due to
the extent of space and span is slightly complicated and is composed of a tensile system of 16 ropes, 34 mandrels, and 78 tent pegs working together.

All these details show that the designer of the tent was a very good learner in absorbing other forms and technology and using them for the tent. He innovatively used methods of building from the small residential tent transplanted to the bigger space of the tent temple.

6-8-3 Biggest black yak hair tent in Nagque

Fig.6-7 (far left), the biggest Black Yak Hair Tent in Nagque. Fig.6-8 (left middle), two Giontas with black rope strap, ridge beam and a T joint. Fig.6-9 (right middle), both transverse and longitudinal frames which consist of multiple T joints. Fig.6-10 (far right), three rows of double T frames.

Stimulated by the success of the Arou Big Temple, the government of Nagque Prefecture decided to build a bigger tent as an exhibit for the 2007 Horse Racing Festival. It was said that the new tent resembled the biggest tent in the history of Baqên County. After seven months, the tent was finished on 30 July 2007 by 120 nomads working successively and the whole manufacturing process was completed only by hand from the very beginning of the cutting of the yak hairs, to their spinning, weaving, and finally sewing.

Since the effective area of 666 square metres for the tent (Fig.6-7) is more than double that of the tent temple, its structural approach has its own principles and system instead of simply enlarging the parts found in smaller tents, making it quite different from the others in coping with the extra-long span. Its characteristics are the following:

a) Instead of transverse frames of double T joints, although its elements lie in a single plane, this tent has both transverse and longitudinal frames which consist of multiple T joints (Fig.6-9).

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284From conversation with Mr. Chunjiang of the Culture and Broadcasting Authorities of Nagqu Prefecture.
Two groups of the transverse and longitudinal frames make two rectangles. The big one consists of 26 T joints which is a rigid frame close to the boundary of the tent roof and wall. The small one consists of 17 T joints which is a smaller rigid frame closer to the tent centre with a higher horizontal level to support the roof. The highest level ridge beam is made of a transverse frame of 5 T joints.

b) There are 4 soft frames outside the tent as well. These frames mainly rely on many tension ropes, poles and foil straps underneath the roofs. This kind of long rope strap is known as a Gionta (as Fig.6-8, the black rope strap which is parallel to the ridge beam) and is 3-5 cm in width. Made of soft and solid yak hair rope or leather, the Gionta runs horizontally around the roof and interface between roof and walls. It thus offers a solid ground as the point of application of the tension ropes. Together they pull the roof out with the side walls hanging vertically.

c) Like the tent temple of Arou, a pile hoop made from metal sheet was widely used at the top end of each T pole with an arch-shape metal bar to bear the load from the ridge beam (Fig.6-11). Special treatment was found at each 90 degree right angle place of intersection where the pile hoop was bent in an almost 90 degree right angle to let the two ends of the separate ridge beams be joined (Fig.6-10), while a T pole with an arch-shape metal bar bears the load of the corner of the frame. Because of the oversized structure (Fig.6-12), a pile hoop was adopted not only for reinforcement of the T poles but also for lengthening beams and poles.

d) According to the Chinese National Standard for Road Vehicles, the total length of all trucks should not exceed 12m, the width of all models should not exceed 2.5m, and all models must not exceed 4m in height. This is for mobile transport in towns, but all components of a large tent should also be minimized in case of yak transport in the mountains. Through the methods used for sub connection, the maximum length of the tent components (beams and poles) is less than 4.5m. This is reasonable and necessary for both the saving of timber and the ease of fabrication and transportation.

In view of these analyses, a conclusion can be reached that this huge tent is a unique combination of frame structure, exterior piles, and linking ropes, all tied up by a heavier felt-like black yak hair cloth

285 中华人民共和国国家标准: 道路车辆外廓尺寸、轴荷及质量限值, Limits of dimensions, axle load and masses for road vehicles, GB 1589-2004
because it is a bigger tent. The complex is based on the reciprocal actions or effects of all components, an attribute which can be utilized in the design of demountable and kit-of-parts structures.

6-9 The BYHT as a Territorial, Cultural and Architectural Complex

Because of its isolated environment and history, very little literature about the BYHT has been left for today’s research. The well-known oral masterpiece, Epic of King Gesar,286 does not even have a hand written form. It is popularly sung in every pastoral area but basically vanishes as soon as it arrives in an agricultural area with the settlement of the pastoralists. It could be for the same reason that western architectural researchers have said that the BYHT “…is very little known; some of it has never been explored.”287 At the time they gave much more attention to the temples, palaces, houses and even bridges of Tibet whilst ignoring the BYHT. This research aims to start addressing this position.

The Tibetan pastoral environment is an important carrier for the survival of the BYHT culture which is intrinsic to the historical ethos of the people of the Qinghai-Tibet. The impact on people from the geographical conditions and religious beliefs is particularly apparent in these areas of harsh natural environment and low productivity.

A Tibetan folk song states that there are black tents wherever the grassland is, and this accords with the fact Tibetan nomads formally regarded black tents as defining their ethnic identity. Without doubt, the Tibetan black tent is a part of a unique cultural landscape. Besides, under the accumulation of ever-growing pressures on the environment, the BYHT is of major immediate significance in promoting sustainable living.

This investigation suggests that the BYHT could have significant contributions to offer a conflict resolution between increasing urbanization and land utilization. The Khan Shatyr Entertainment Centre opened on July 5th 2010 in Kazakhstan, is the world’s tallest tent-like structure, but this is using the tent in a modern way as a way of making architectural form. However, more flexible and scattered structures linked to a way of life could be more beneficial to the environment if viewed from a sustainability aspect. Thus, it is of vital significance for research into the BYHT to understand its

286 The Epic of King Gesar is the central epic poem of Tibet and much of Central Asia. With about 140 Gesar ballad singers surviving today (including singers of Tibetan, Mongolian, Buryat and Tu ethnicities), it is prized as one of the few living epics. The epic, believed to be approximately 1000 years old, concerns the fearless King Gesar, who ruled the legendary Kingdom of gLing.

historical and practical functions, explore its use factors and contemplate how it could be used in harmony with modern culture.

![Fig.6-11 (left), exploded view of a T-joint. Fig.6-12 (right), isometric view of whole structure of interior frames.](image)

**6-10 Parallel Between BYHT and Modern Events Buildings**

Obviously, there is a remarkable contrast between the two environments where they are respectively situated. The former is characterized by very tough natural surroundings such as very high altitude, cold climate, very thin air and remote location, while, the latter is often surrounded by dense urban development, mass transit of people and vehicles, and consequent urban events. The essential characteristic of both is employing a dynamic form, thus making buildings capable of adapting to the local conditions for maintenance, survival and development both in their own environment and sustainably.

Although the formation of BYHT culture occurs because of low productivity and especially the nomadic mode of production at local level, the BYHT has a long tradition and has proved itself a sustainable form of man-made living environment. Compared with this, the realization of mega-event buildings is happening in a world of higher productivity and availability of advanced technologies and materials, yet the buildings made are not nearly as sustainable as the BYHT. This is the key point. The BYHT forms a useful model because it shows how exhibition buildings can still be created in places where resources are very scarce. In this sense, the BYHT can serve as not only a system for sustainable living or vernacular cultural display, but also as a comparison for a direction of development in the design of future mega-event buildings. Thus, it makes a significant contribution to offering a resolution to the conflict between increasing urbanization and virgin land utilization.
CHAPTER 7  CHINESE TIMBER BUILDINGS AND THE FEASIBILITY OF DEMOUNTABLE BUILDINGS

As has been argued in above chapter, the traditional hand prefabricated exhibition hall of the BYHT has reached a certain critical point in terms of technology and environment. It is true that the BYHT has been playing an essential part in the ecological system of the Tibetan prairie and that tent living will continue to be something important to the Tibetans. However the BYHT has developed and exists in the very tough natural conditions characterized by high altitude, cold climate, very thin air and remote location. If the desire is to transplant this successful sustainable system directly into the host city of a mega event, it will seem an anachronism in this era of the internet and over-urbanization. What is needed is to apply the experience enshrined in the BYHT because of the local conditions rather than copying it mechanically. The BYHT exhibition hall affords lessons that merit attention rather than being a true solution for everywhere and it should not be regarded as a generic model. This is because a dense population, mass concrete structures and apparently fast moving physical surroundings are the essential characteristics of the modern city and also the indispensable condition for the maintenance, survival and development of the city, as well as being the preliminary requirements for the successful holding of events. For sustainable design, well researched environmental issues that pertain to the place, time and local culture will be the key to developing new ideas about temporary architecture.

7-1  Mega Building: Starting with Small Concepts

Obviously, the recycling of building materials is a partial solution to building reuse but it may not serve when considering the whole issue. Although building demolition is not the reverse situation to the process of fabrication, it may be a starting point for building a new theory.

A theory is a good theory if it satisfies two requirements: it must accurately describe a large class of observations on the basis of a model that contains only a few arbitrary elements, and it must make definite predictions about the results of future observations.288

The easiest way to demolish a building is to make it in way such that it can be taken apart in the same way in which it is erected. This idea comes from sets of toy blocks (also building bricks, building

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blocks, or simply blocks), which are wooden, plastic or foam pieces of various shapes (square, cylinder, arch, triangular) and colours. This small game conceals the dim desire of all human being to make the world. As the ancestor of the building block:

...the alphabet block was introduced in 1693 when John Locke, an educational philosopher, announced that dice and playthings with letters on them would serve to teach young children how to read. In the early 1700s, Friedrich Wilhelm August Froebel, the pioneer of the kindergarten movement, introduced carved wooden blocks that had letters imprinted on them. In 1820, S. L. Hill of Brooklyn patented ‘ornamenting wood,’ the process of painting a block of wood, embossing it with a design and adding another colour of paint to create multicoloured designs in wood.289

The key thing about such blocks is that the method of building, the fact that they are simply stacked and hold together under friction and gravity, has an exactly reverse process of ‘un-building’ that does not destroy the blocks or the forces that hold them together.

Architectural blocks flourished in nineteenth-century Germany: one representative catalog published by a Nuremberg merchant circa 1800 listed building sets for castles and walled towns. In America, building blocks were recommended to parents in 1826 as a toy to teach “gentle manners” to young children; and by the late 1860s, Charles Crandall’s “tongue-and-groove” interlocking blocks had achieved a popularity that foreshadowed the later success of systems such as Lego.290

As one of the many systems of modern toy blocks, Lego stands out as a kit-of-parts for making and remaking models. In reference to kit-of-parts thinking in the construction industry, which usually refers to a series of design elements that can be assembled to make a permanent building, a Lego product has a much longer life cycle. This is because Lego components can easily be reassembled according to various intentions, whether these intentions are valuable or not. However, Lego itself is not the answer, as the James May full-sized Lego house, now demolished and with the blocks donated

289 Richford, N. History of Alphabet Blocks | eHow.com http://www.ehow.com/about_4597646_history-alphabet-blocks.html#
A Lego house might be alright to camp in overnight but it would not work as a permanent dwelling in the climate of the UK. However, Lego is just the initiation of the thinking necessary to design appropriate kit-of-parts buildings both because of the difference in scale and the other parameters of architecture in the urban context, such as the need for weather proofing.

7-2 Kit-of-parts and Chinese Wood Structures

One of the features that appeals to people in the exhibition hall of Ancient China's Technology and Science in the China Science and Technology Museum is the research mystery of the Lu Ban lock (Lu Ban Suo). Actually, the lock is known by different names, such as the “puzzle knot,” the “Devil’s Knot” (Teufelsknoten in German), the “Chinese Cross”, the “Kong Ming Lock” (Kongming Suo) and Six-Piece Burr puzzle. Because some details of its history are lost, some say it is a Chinese invention, but Jerry Slocum's investigation into the history of the Six-Piece Burr now traces it back to at least 1698 in Germany.

This kind of three-dimensional puzzle toy with its meshing interior concave-convex pieces is very ingenious. There are many types of Lu Ban lock toys with various shapes and internal structures. Generally they are easy to disassemble and hard to reassemble. When reassembling them, a child (or even an adult) needs to observe, ponder and analyze the internal structure carefully.

The essences of the Lu Ban lock toy stems from the structure of the tenon and mortise joint system which was invented by the Chinese in their ancient architecture. Evidence of these joints has been found in the wooden ruins of Hemudu in Yuyao County, Zhejiang Province, China, dating back more than 7,000 years. In traditional Chinese architecture, wood components such as beams, brackets, roof frames and struts were made to interlock with perfect fit, without using fasteners or glues, enabling the wood to expand and contract according to changes in humidity. Archaeological

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292 Lu Ban, together with his wife Lady Yun, is considered the patron saint of carpenters and the original master of wood joinery. Lu Ban lived in the Spring and Autumn period (770-476 BCE) and is credited with various inventions including the saw, the carpenter’s plane and the ink (chalk) line.


evidence from Chinese sites shows that by the end of the Neolithic Age, mortise and tenon joinery was employed in Chinese construction.  

The tenon and mortise structure as found in the Lu Ban lock is widely applied in construction systems and in furniture making, but with a focus on a different technical level. In construction the stresses on the joint are vital for structural stability. Because the mortise part can be excavated in several directions, this will combine the forces coming from different directions at the same point and in so doing close up, when it becomes a high strength perfect whole. Thus the joint, because of its slightly loose fit, behaves as a flexible node in terms of structural mechanics, rather than a rigid node, as would be found in welding. When the innumerable tenons and mortises combine together, the whole structure will present a situation of an extremely complex and subtle balance. The main reason for the structure not breaking is because every single tenon and mortise is both strong and yet flexible, as is the timber itself.

The bucket arches or Dou Gong found in Chinese historic buildings are a system of brackets which occupy a unique place in traditional Chinese architecture. In addition to adding to the sumptuous magnificence of these buildings, these brackets are arranged like baskets of flowers to be set under the overhanging and upturned eaves, and make the ancient Chinese edifices both graceful at the time of construction and enduring. Similar to the Lu Ban lock in shape, the bucket arch offers ancient Chinese wooden structures a great capacity for earthquake resistance. Among many preserved ancient wooden structures, the Dule Temple in Ji County of Tianjing and the Wooden Pagoda in Ying County, Shanxi Province in North China are particularly conspicuous in their anti-earthquake performance.

Guanyin  

Buddha, Avalokitesvara

Ge is a kind of Chinese building of two or more storeys, which is noted for lattice doors or winding corridors with banisters round. It can provide people a vantage point for looking far into the distance, worshiping Buddha, storing books, strolling about or having a rest.  

Liao Dynasty (907-1125 CE).  

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297 Buddha, Avalokitesvara

298 Ge is a kind of Chinese building of two or more storeys, which is noted for lattice doors or winding corridors with banisters round. It can provide people a vantage point for looking far into the distance, worshiping Buddha, storing books, strolling about or having a rest.

299 Liao Dynasty (907-1125 CE).
dignified but also give it an imposing appearance (Fig.7-1). It resembles a two storey building when viewed from the outside. In fact, there are three storeys. The middle storey is merely a supporting structure and hidden without having tiled eaves thus giving the whole building a simple silhouette. There are platforms both inside and outside the building which offer places for the worship of Buddha and to lean against the railing to look out into the distance, making them both practical and artistic.

Being 67.31 metres high, the Yingxian Wooden Pagoda in the west of Shanxi Province is another classic wooden high-rise building built in 1056 (Fig.7-2). The plan and outside appearance of the pagoda are octagonal which is conducive to resisting the distorting force generated by seismic waves. The brick and stone base of the wooden tower, reaching as high as 4.4 metres, are sufficiently solid and stable to bear the entire weight of the tower which is approximately 1300 tons. The connections of the inner beams and columns are completely set up through the bucket arches, and all kinds of components are joined using tenon and mortise joints. The entire tower's primary members do not use a nail or rivet except in the stone base. This form of connection of the primary members is similar to a state of semi-consolidated or semi-fluid hinges that can withstand greater bending moments. The diameter of the ground floor is 30 metres. It has 5 floors and 6 eaves looking at it from outside. In fact, every floor has an inner layer, so it has 5 floors outside and 4 floors inside, making 9 floors altogether. Every floor is supported by wooden pillars both inside and outside, and about 60 kinds of inclined beams, wooden stumps and short pillars were used between the main wooden pillars, thus forming a wooden structure of repeated beams. According to the records in historical documents, the Yingxian wooden pagoda used 3500 cubic metres of wood. Pine and elm were widely used because pine cannot be deformed and elm is very solid.300

7-3 Tenon and mortise joints and the aseismic mechanism

Temporary buildings where the structure is made from a kit-of-parts often come under criticism for their less than perfect solidity, and specifically, for their ability to resist lateral wind and seismic forces. Although there is no historic record showing the ancient Chinese used to build houses using the demount ability concept the techniques they used would be appropriate for this approach. Today kit-of-parts architecture, probably because of the difference in residential culture and the desire to

accord with systems such as Fengshui,\(^{301}\) is not as popular in China now as in western countries. However the concept has been traditionally used in the production of bracket sets (bucket arches) and their tenon and mortise joints.

Bucket arches were once a very important component for the transmission of forces and were commonly used in Chinese timber structures. Because of their use, the double-eaves roof of many timber buildings can take a projecting form that is both exquisite and typically Chinese. The essence of the transmission of forces of the bucket arches is through the transition to deliver the loads reliably from the upper structure to the beams or pillars. Although this kind of system seems a precarious balance, in fact, it is a relatively steady system mutually depending on many pairs of connections through layer upon layer of the structure, horizontal and vertical. As the brackets are loaded from above, the components of the bucket arches form a tight body, depending on the tightening of the tenon and mortise connections. The final steady state is not reached until the building is finished. However, there is some redundancy in the system which allows for maintenance. For ease of restoration and replacing any damaged elements or even entire components, the nodes of tenon and mortise have to be designed to be demountable. Moreover, the procedure of opening must be the exact opposite of the original installation procedure. The situation sometimes arises when the damage to a wooden construction is serious, and the rebuilding means subjecting all parts of the whole building to systematic demolition and rebuilding.\(^{302}\) This kind of rebuilding mode, for the Chinese, is considered to be a last resort when the building undergoes the most severe or unfavourable damage. As mentioned before, this kind of idea of rebuilding can also be seen in Japan. For example, the Ise Grand Shrine\(^{303}\) buildings at Naikū and Gekū, as well as the Uji Bridge, are rebuilt every 20 years as a part of the Shinto belief of the death and renewal of nature and the impermanence of all things (wabi-sabi). This rebuilding is also a way of passing building techniques from one generation to the next. The rebuilding of the main shrine takes place on an adjacent site next to the old, and each rebuilding alternates between the two sites.

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\(^{301}\) Fengshui: mantic omen, in ancient China, the location of a house or tomb is supposed to have an influence on the fortune of a family or clan. It is still quite popular especially in the southeast China.

\(^{302}\) Demolishing and rebuilding, text proper in Chinese: 落架重修.

\(^{303}\) 伊勢神宮, Ise Jingū
Through the application of interchangeable parts in the bucket arches with their tenon and mortise joints, ancient timber structures in East Asia meaningfully represent the replace ability of components and, to some extent, building flexibility. However, because of the limitations and disadvantages of timber, production equipment, and craftsmanship, an appropriate definition of the jointing system is that it is half-rigid. So, what kind of procedure and measurement were adapted for increasing the solidity of timber buildings and specifically their lateral stability? Friction, as the term is understood in mechanics, is the resistance to relative motion between two bodies in contact. As friction manifests itself as a resistance that opposes motion, it is usually considered to be a nuisance, but the major concern for the issue of tenon and mortise joints is to maximize this resistance to reduce movement. The top priority for the timber building system is designing to generate as much frictional resistance as possible; if the system fails the building will collapse. What, then, is the answer to these issues?

7-4 What Makes a Good Design Solution?

Continuing to examine the two buildings mentioned above, indigenous design had to work out the principal of the increasing stiffness of the total building. Without resorting to sophisticated technology and expensive metal materials, a thousand years ago designers were left with a ‘small bag of tricks’ with which to conquer this problem. The basic solution evolved through limiting each single element’s movement from one to two directions and making the element as a whole body, or through parts connected by tenon and mortise joints, to combine a group of small elements into big components. The former is similar to the idea of a reciprocal structure and the latter is somewhat similar to the concept of a framed structure as found in modern buildings although the traditional solution was not based on calculation as in a modern structure, only experience.
The Dule Temple’s slanted struts and forked struts, making use of the stability of a triangle which is helpful to the integrally structural joints of a building, play an important role in the frame. Many slanted struts were used in the hidden storey to prevent its deformation. In addition, the mantis-like tenon and mortise joint, whose plan shape looks like a mantis with a big head and a slender neck, provides a tremendous tensile strength. During the thousand years of its existence, the Dule Temple has survived several strong earthquakes, with the Guanyin Ge remaining lofty and firm. Viewing the section of the Guanyin Ge (Fig. 7-1), the whole structure of it can be seen as separated and merged in the horizontal plane. When separated, it is divided into three structural layers, and when merged, it becomes a core body. To avoid deformation, the core body of the ground and second floor are built as a hexagon and a rectangle respectively. Therefore the whole is reinforced rigidly as well as conveniently constructed.\(^{304}\)

The obvious difference between the Yingxien Wooden Pagoda (Fig. 7-2) and other timber pagodas is the design of its inner structure. During the time of the Sui and Tang Dynasties, the people constructed the tower by setting up a straight pole in the interior of the ground floor with an exterior ring of outer peripheral columns. This method as well as facilitating the construction also increased the overall turning capacity. Significant improvements in the interior structural design were then made. Instead of a pillar inside the circle, a ring of 6 inner slotted columns was designed, so that the internal fulcrum was replaced and went from being a point to being a surface. By doing that, the core space formed by the inner ring could be used for a statue of Buddha, and the space in between the 6 inner slotted columns and the 12 outer peripheral columns could serve for the circulation of people. Therefore the layout of the interior space as well as the structure was more effective and reasonable. These improvements obviously enhanced the overall rigidity of the structure as well as its ability to resist tilt, which are both extremely important to ensure adequate stiffness to resist lateral forces induced by wind, seismic, or blast effects. This design idea is similar to the principle of modern structural design for high-rise and extra-high buildings when designed as a framed-tube and tube-in-tube structure. Perhaps the inspiration for this modern design comes from the internal core tube of this very old building.

7-5 Earthquakes and Historic Buildings

The region where the Guanyin Ge of Dule Temple is located has historically been prone to seismic activity. Jixian county once belonged to Hebei province but is now part of Tianjin city. The North China earthquake zone includes all or part of the areas of Hebei, Henan, Shandong, Inner Mongolia, Shanxi, Shaanxi, Ningxia, Jiangsu and Anhui provinces. The intensity and frequency of earthquakes in this zone rank second among the five seismic zones of China, just after the Qinghai-Tibet Plateau (Northwest China) Seismic Zone. As the capital city is located in this area, it has drawn significant scientific study. According to statistics, the area has documented five occurrences of magnitude 8 earthquakes and a further eighteen occurrences of 7-7.9 magnitude earthquakes. In addition, it is located in a well-developed metropolitan area which is densely populated, and of political, economic, cultural and transportation importance, despite facing the very serious threat of earthquakes.

The North China earthquake zone is divided into four seismic belts. The North China plain seismic belt where the Guanyin Ge of Jixian County is located is one of the four. Generally its southern boundary follows the Xinxiang–Bengbu line, the northern boundary is in the south of Yanshan, the west boundary is to the east of the Taihang Mountains, the eastern boundary is in the depression of the western edge of the Lower Liaohe – Liaodong Bay, and the southern extension reaches to the southeast of Tianjin going south of Jinan up to the east of Suzhou. This earthquake belt poses the greatest threat to the metropolitan areas of Beijing, Tianjin and Tangshan, which are usually called the Three Big City Circles in China. In 1679, the biggest earthquake in Chinese history, the 8.0 magnitude earthquake of Sanhe and Pinggu counties in Hebei, took place in this belt. According to statistics, there were in total 140 earthquakes of at least magnitude 4.7 which included five of magnitude 7-7.9 earthquakes and the above mentioned one of magnitude 8.0.

Another serious event happened almost 300 years later. The Great Tangshan Earthquake was a natural disaster that occurred on July 28, 1976 with the epicentre of the earthquake near Tangshan in Hebei a straight-line distance of less than 80 km away from Dule Temple in Jixian County. The Tangshan earthquake is believed to be the largest earthquake of the 20th century in terms of death toll.

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306 Text proper in Chinese: 王维编辑: 中国地震带的分布 2008-05-14, 中国科学院地球环境研究所. Institute of Earth Environment, CAS, Xi’an
307 Ibid.
Chinese government official sources state a magnitude of 7.8 on the Richter magnitude scale, though some sources have listed it as high as 8.2. The first event was followed by a major 7.8 magnitude aftershock some 16 hours later, increasing the death toll. The earthquake devastated the city over an area of roughly 6.5 kilometres by 8 kilometres, and hundreds of thousands of buildings were destroyed. Many of the people who survived the initial earthquake were trapped under collapsed buildings. Tremors were felt as far away as Xi'an approximately 760 km away. Eighty-five percent of the buildings in the city collapsed or became uninhabitable. The seismic waves spread far, with damage in cities such as Qinhuangdao and Tianjin, and even a few damaged buildings as far away as Beijing, 140 km from the epicentre. Only one hour's drive away from Tangshan city, Jixian town had many houses that collapsed, but the whole structure of Guanyin Ge was basically safe although the frames and brackets were heard creaking for a long time afterward. The inspection after the shock found that the iron bar that connected a column with the back of the statue of Avalokitesvara was broken, and the waist of the statue was cracked. In addition, the columns of Guanyin Ge and the Gate were slightly inclined inward. In contrast, the following two cases are worthy of more attention.

a) The white pagoda is located in the southwest of corner of Jixien, just 380 metres due south of Dule Temple. The Dule Temple tower, also called the White Pagoda of Guanyin Temple, is commonly known as the Bai Ta (white pagoda). Being a masonry structure, it was constructed in the Liao Dynasty as a hollow octagonal tower. The tower's height was 20.6 metres. When the Tangshan earthquake struck, Bai Ta was severely damaged. The Tasha, which are a Buddhist ornamentation decorating the upper story of a pagoda, fell down with the shock, and the body of tower was split by the earthquake. In 1982, the tower became the subject of a reconstruction process.

b) Fushan pagoda is located a 20 km straight-line distance away from Jixian town to the south of Cuiping Lake. Built in the Liao Dynasty, this tower is built in brick but in imitation of the wooden pavilion type with an octagonal plan. The original tower height was approximately 19.45 metres. When the 1976 Tangshan earthquake struck, this tower was severely damaged as well. The tower body above the fourth level was shaken completely to destruction, and the east side of the tower body was cracked all through. The remaining tower had a height of 16 m and

was in danger of collapsing. In 1985 the Fushan tower was rebuilt by the State Bureau of Cultural Relics and the Tianjin Municipal People's Government.

A conclusion can be drawn from the experience of these old pagoda structures in the 1976 Tangshan earthquake. When the earthquake struck, the Guanyin Ge had an extraordinary ability for resisting its effects. The credit goes, in the first place, to its unique structural design.

Shanxi, home of the Yingxian wooden tower, another important heritage pagoda in China, is also an earthquake-prone region, and according to historical records, twice earthquakes over magnitude 8 have occurred. One time was in 1303, with an intensity of magnitude 11; the second time was in 1695 with an intensity of magnitude 10. Besides these two super earthquakes, the wooden tower has also undergone a dozen below magnitude 8 earthquakes. In recent years, the effects of earthquakes in Xingtai, Tangshan and Inner Mongolia’s Holinger\footnote{Text proper in Chinese:1976 年和林格尔 6.3 级地震前后震兆特征分析. 地震研究. 卷(期): 2001, 24(3). Zhang, Z. et al. Analysis on Earthquake-Precursor Characteristics before and after the Ms 6.3 Holinger Earthquake in 1976. Journal of Seismological Research} were felt here. In particular, the 1976 Tangshan earthquake which struck only 600 km away from Yingxian affected the county, shaking the whole pagoda and causing wind chimes mounted on the tower to ring loudly for approximately 1 minute but the Yingxian Wooden Pagoda in Shanxi was unharmed.

7-6 The Dynamic Characteristics of Historic Buildings

Research into the dynamic characteristics of these historic buildings started in the 1970s, but as a result of technical limitations, these research investigations were insufficient. With the increasing attention being given to recent global earthquakes, people have started to give more attention to the earthquake resistance mechanisms of historic buildings. Therefore, in-depth study of ancient wooden structures based on the tenon and mortise joint, including the mechanical properties of the structure, have been carried out in the hope of gaining a deeper understanding of the basic principles of aseismic performance. This includes the dissipation of energy and absorption of shock in such wooden structures. This is very important not only for the protection and restoration of architectural heritage, but also because the tenon and mortise connection is considered to be a semi-rigid connection, which
is situated between hinged and rigid connections. The riveted and bolted connections of modern types of kit-of-parts architecture are, in many cases, also semi-rigid connections. This is significant in that the design and planning of a kit-of-parts structure can definitely profit from the successful experience of historic wooden structures.

On May 12, 2008, a magnitude 8.0 earthquake occurred in Wenchuan County of Sichuan Province, which spread to Gansu, Shaanxi, Chongqing, Yunnan, Shanxi, Hubei and other provinces and cities, and caused unprecedented damage to many precious cultural heritage buildings. After this earthquake, the seismic performance of Chinese ancient buildings has become an important topic, and a great number of papers have been published on the subject. Analysis was done on the phenomenon of some standing wooden trussed roofs of ancient buildings after a strong earthquake when walls had collapsed, however this discussion will pay more attention to the theoretical and experimental findings as a proof of the relationship between tenon and mortise joints and aseismic mechanisms.

A test supported by the National Science Foundation of China was carried out at the Structural Engineering and Earthquake Resistance laboratory of the Ministry of Education in Xi’an, China. This used pseudo-static tests to model mortise-tenon joint structures and bucket arches. The results show that when being squeezed into each other the mortise and the tenons would get an overall plastic deformation under a horizontally reversible action, which leads to looser connection between them, and degeneration of rotational rigidity as well as making evident the flexible characteristics of mortise-tenon joints. Consequently, there is a greatly reduced possibility of damage to the structure. Similarly, the deflection stiffness of the bucket arch is always going down no matter whether the action is increasing or decreasing.


315 Some aseismic behaviours of transferal to a structure, such as hysteresis behaviours, energy dissipation capacity and failure patterns, are carried out by the pseudo-static test and the shaking table test.
On the basis of the hysteresis loops\textsuperscript{316} of the mortise-tenon joint (Fig. 7-3, lower left) and the bucket arch (Fig. 7-4, lower right), two corresponding mechanical models\textsuperscript{317} can be established respectively. As a result, a hysteretic energy dissipation factor (\(\phi_{hed}\)) which can quantitatively evaluate the energy dissipation capacity of the mortise-tenon joint or the bucket arch can be established. Furthermore, the corresponding theoretical calculated formula for \(\phi_{hed}\) is also found, as well as the values of \(\phi_{hed}\) corresponding to the mortise-tenon joint models and the bucket arch models respectively. The results show that, the \(\phi_{hed}\) for the bucket arch models are about 1–2 orders of magnitude bigger than those of the mortise-tenon joint models. Hence, it is confirmed theoretically that the bucket arch structure is the main vibration reducing and shock isolating construction system in ancient Chinese timber buildings.

![Fig. 7-3 (left), the mortise-tenon joint, source: http://www.360doc.com/content/09/1215/21/13887_11214459.shtml](image-url)

![Fig. 7-4 (right), the system of the bucket arch, source: http://www.guoxuecc.com/xianfeng/2008/3031.html](image-url)

As an example of an ancient timber tower, the Yingxian Wooden Pagoda is in urgent need of repairing and reinforcing. This is because of a variety of natural factors such as timber corrosion, earthquakes, and wind that have produced an overall tilt and various other defects. As part of an investigation into its condition some papers\textsuperscript{318} based on site measurements, describe and analyse variations in the distance between adjacent inner slot columns in the same floor and the differences of the inner slot columns in the adjacent floor, finding that these are unequal and the tower’s octagon is distorted.

\textsuperscript{316} Classically a hysteresis loop shows the relationship between the induced magnetic flux density (B) and the magnetizing force (H). It is often referred to as the B-H loop. A great deal of information can be learned about the magnetic properties of a material by studying its hysteresis loop. Some structural deformations follow similar hysteresis characteristics.

\textsuperscript{317} As the paper discusses, these are the restoring moment-rotation models of bucket arch and mortise-tenon joint systems, as well as the bilinear force-displacement relationship of the bucket arch models.

Other research investigated the dynamic characteristics and damage mechanics of the tower experimentally and numerically by using micro tremor measurements and the finite-element-method (FEM). The micro tremor measurements are conducted on the tower (each floor) and the surrounding ground. From the micro tremor observation data, the predominant frequency of the surface ground and natural frequency, vibration mode and the damage distribution characteristics of the tower were evaluated. Based on the experimental studies, a finite element model of the tower was created. In order to simulate the mortise and tenon joint system and bucket arches in the structure, which form a combination element in timber structures, a special beam-element group was developed. Numerical simulation of the seismic response of the tower shows that the second and third floors of the tower would be damaged more seriously than other floors because of their severe stresses when acted on by seismic loading. The overall analysis of the tower shows the same phenomena.

7-7 What is the Implication for Modern Demountable Buildings?

The urgent environmental problems and impacts of buildings have suggested that another approach to building construction may be necessary. It is also of importance in protecting and rehabilitating the ancient architectural culture of China to study the structural characteristics of ancient Chinese timber architecture. An understanding of this is helpful in order to recognise the achievement which has been made, but more importantly, it can provide both enlightenment and a reference point for conveying the study of modern demountable building into a deeper and wider development.

Looking back at the seismic performance of ancient Chinese architecture, because of timber characteristics and the inaccuracies of hand working, slight crevices and slackening can be produced in the bucket arches or mortise-tenon joints, which taken together appears to be a shortcoming. But when a strong earthquake takes place, this shortcoming can be converted into an advantage, even if this is unconscious, as these slackened bucket arch and mortise-tenon joint systems produce a cushioning effect on the energy in the waves, thus greatly attenuating the destructive energy of an earthquake. This ties in with the fact that the skeleton construction systems and the nodes used also have a certain room for man œuvre, which, to some extent, reduces the earthquake damage.

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319 The finite element method (FEM) or finite element analysis (FEA) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as of integral equations.

320 Ai LanChe et al., 2007, Evaluation of Dynamic Behaviours and Damage Mechanism of Ancient Timber Architectures, Key Engineering Materials (Volumes 340 - 341)
However, if from some existing examples, the deduction is made that all ancient Chinese wooden buildings are earthquake resistant this does not square with the facts. According to a historical record, an earthquake of magnitude over 8 occurred in Shanhe and Pinggu counties during the Eighteenth year of the Kangxi Dynasty, in 1679, and no official buildings or residential houses survived. Only the GuanyinGe pavilion of Dule Temple did not collapse. This may be attributed to the high standard of construction and the quality of materials used for religious buildings. In Chinese history in both Tang and Song Dynasties there was a nationwide trend to build temples and Chinese Buddhist construction reached its heyday in the Tang Dynasty; however, there is only one timber temple left now from this period, which is the Great Hall of Foguang Temple. Detailed and objective analyses have revealed the real reasons for buildings surviving, which is the use of special structural measures to strengthen the overall spatial rigidity.

7-8 The Application of Tenon and Mortise Joints

7-8-1 The advantages in using tenon and mortise joints

The system of tenon and mortise joints is also of vital importance in the development of Chinese furniture. The use of the tenon and mortise jointing system in Chinese furniture can be classified according to how it contributes to the structural integrity, in terms of three types.

a) The first type mainly serves as the joint between one surface and another which can be of two kinds of plane joints; it can be used for joining two sides together, and can also be a transfer of forces between surface and edge.

b) The second is the structural approach of a point that is mainly used for combining horizontal and vertical timber members into a T-shape, corner or cross-linking, as well as joining straight or curved wooden members.

c) There is also a third structural method for where three or more components are grouped together or interconnected with each other. This method, besides utilizing the other two kinds of jointing tenon and mortise structures, is more complex and used only in specific situations.

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321 Text proper in Chinese: 王士祯《居易录》“己未（康熙十八年，1679年）地震，官廨民舍无一存，独 [观音] 阁不圮”

322 Foguang Temple (Chinese: 佛光寺) is a Buddhist temple located five kilometres from Doucun, Wutai County, Shanxi Province of China. The major hall of the temple is the Great East Hall, built in 857 AD, during the Tang Dynasty (618–907). According to architectural records, it is the third earliest preserved timber structure in China.
There are advantages in using tenon and mortise joints in furniture.

a) Tenon and mortise structures are part of the transition of forces and combination of wood elements, between long and short, fat and thin. This jointing system can effectively limit the movement of wooden elements in all directions. A nail connection cannot do this. For example, two wooden doorposts joined with a nail to make a T-join between vertical and horizontal members can easily be twisted to change the angle. If the same connection is made with a tenon and mortise joint it will not be distorted.

b) Furniture made with tenon and mortise jointing is advantageous for transportation and repair. Much padauk teak furniture is dismantled for transportation, and then re-erected at the destination, which makes for convenience.

c) Pure padauk teak furniture may be used for hundreds and thousands of years. If problems emerge, for instance, a chair leg being damaged, it can easily be replaced instead of replacing the whole chair, something that is not possible in furniture joined with nails or screws.

d) In most cases, adhesive has been used as reinforcement for joints. In ancient times glue was made from the swim bladder of the yellow sturgeon. After beating with a hammer, grinding, crushing, and steam boiling, this natural glue’s characteristic was advantageous for making repairs easily. The glue dissolves after heating, so the repair can be done by disassembling the piece of furniture and replacing worn or damaged parts. Nowadays, a new glue made from chemical adhesives has been invented specifically for hardwood furniture. The advantages of it are characterized by being easy to use, high coherency and toughness, hygienic, and having a good appearance. But its use makes furniture hard to disassemble for repair or replacement of components.

e) If the elements of hard padauk teak furniture are connected with nails, because the nail is squeezed by the strength of the hammer blows and wedged into the hard wood, this process is likely to split it. In addition the metal easily corrodes or oxidises. So even though the wood is undamaged the joint can discolour or fail because of loss of structural integrity. By using tenon and mortise joints when making padauk teak furniture, the tenon itself is conjoined with the furniture, as there is material consistency and hence longer furniture life.

7-8-2 Using tenon and mortise joints in furniture
Chinese furniture in terms of both tenon and mortise joints and structural framework is very complete; both complement each another and are indispensable. The frame structure provides the context and the basis for the tenon and mortise joint, but the tenon and mortise joint allows the linear elements to be made into a three dimensional form. In the design of furniture there is a wide variety of types, but no matter how diverse these are, their physical structure has utilised the basic principles of wood construction of the truss and frame. The craftsmanship of Chinese padauk teak furniture has inherited the method of truss structure exactly. As Fig.7-5 shows, the four sides of the “wall” of the queen-sized padauk teak bed were made from 8 demountable parts, and each of them consists of a member made up as a lattice using hardwood tenon and mortise joint like a space grid. Four columns and the beams join them at top and bottom to work together to form a stable structure, with obvious roots in building technology. This bed is a typical example of ‘multum in parvo’, as well as a miniature model of future kit-of-parts building.

Fig.7-5 (left), the queen-sized padauk teak bed, source: www.sddaily.com. Fig.7-6 (right), a model of a reciprocal frame structure, source: http://www.biagiodicarlo.com

7-8-3 The reciprocal frame

Fig.7-6 upper right shows a model of a reciprocal frame structure which can easily be turned into a very inexpensive roof structure made from logs. The reciprocal frame roof results in a very strong self-supporting structure with unique features. In the structure each beam both supports and is supported by other beams in it. A minimum of 3 beams is required to create a reciprocal frame roof. As each beam supports the next in a reciprocal manner no internal support structure is required. Only the outer end of each beam requires support which will normally be a post used for the wall. The roof
loads are transferred to these posts and then to the supporting foundation. The beams can be fabricated from timber, laminated wood, steel or reinforced concrete. In many cases it will be necessary to notch the bottom of the beams so that they will fit properly together. This notch is complex both in its design and execution and has similarities with the Lu Ban lock.

The principles of the reciprocal frame have been widely applied in architectural precedents including many stunning examples that range from low environmental impact buildings and self-built examples in the UK and USA, to the fascinating and elegant structures of the Puppet Theatre in Seiwa, Tokyo's Spinning House, the Sukiya-Yu house, the Toyoson Stonemason museum and the Life Sciences Laboratory, Torikabuto in Japan. The principle of the reciprocal frame can also be seen in many modern furniture design.

7-8-4 Some instances of assembly system

It is generally thought that Japanese’s wooden architecture was influenced by the system of Chinese traditional wooden structure. Japanese’s wooden architecture is distinguished by more than longevity, resiliency, ingenious and complex in design. Fig.7-7 shows the Japan Pavilion designed for the International Exposition in Seville in 1992 which was an excellent example of an assembly system of wooden beams and columns as well as the world's largest wooden structure at the time. Another example of the wooden assembly system was built in Aichi, Japan for the GC Prostho Museum Research Centre which was set up in 2010 by using 6000 sticks. The museum's structure obviously came from the traditional wooden toy of Cidori sticks. However, the original 12 x 12 mm wooden sticks were enlarged to 60 x 60 mm to form a stable and precise combination of cells. The final result is very elegant (Fig.7-8), being a 9 metre high three-dimensional wooden crystal lattice. Because of the use of the highest quality Japanese cypress, this wooden construction was made entirely without screws, glue and nails.

Therefore, the buildings highlight the epitome of hand craftsmanship and vernacular characteristics, appearing as a giant, abstract grid composed of thousands of wooden sticks. Although, both were built

323 Popovič, Olga (2008), Reciprocal Frame Architecture, London: Architectural Press,
324 The assembly system of cidori, a traditional Japanese building set for children like burr or Lu Ban lock. Cidori is a collection of wooden sticks that can be notched together to make longer or shorter components. It works without metal hinges or nails.
in wood, traditional materials of the country, their success has been not only to defy machine-made structures and modern building materials, but also to exemplify how the small can be made great by sticking rigidly to an authentic Japanese style.

Fig.7-7(left), Japan Pavilion designed for the International Exposition in Seville in 1992, source: http://en.wikiarquitectura.com/index.php/Japan_Pavilion_for_Expo%2792. Fig.7-8 (right), the GC Prostho Museum Research Centre in Aichi, Japan, source: http://www.framemag.com/news/1684

7-9 Brief Summary of this Chapter

After the comprehensive case study of BYHT, this chapter further explores more examples of demountable buildings and structures based on the illustration of the relevant ancient and modern views at home and abroad. Although they differ markedly in morphology, design idea and construction method, they have the same characteristics, being made with wood according to traditional techniques. Through the study of these cases, following significance can be deduced:

- The history of Chinese timber buildings shows that this approach can lead to very long lived buildings, which is another characteristic of buildings that are more sustainable.
- Under the condition of the semi-rigid connection of the tenon and mortise joints, somewhere between a hinged and rigid connection, the properly structured timber buildings have not collapsed even though they have experienced many strong earthquake shocks in their thousand year life. This suggests that the design and planning of a kit-of-parts structure for modern and large scale city events can definitely profit from the successful experience of historic wooden structures.

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Wood is a light material and easier to use in construction than other materials. Although its strength is less than that of iron and steel, generally, the seismic performance of timber is significantly better than other materials. This is partly because the wood itself has high resistance to impact load and cyclic fatigue damage. Another factor which should not be ignored is the use of tenon and mortise joints and beam-column components in traditional wooden structures. This leads to the seamless formation of a structure, highly comparable to that of a modern framework, which forms a kind of reciprocal and holistic frame system.

All case studies in this chapter deliver a clear message that the assembling system of kit-of-parts architecture has the potential to make the bigger spaces or longer spans of the modern standard mega event hall. Conditioned by many factors, historical wooden demountable buildings including the BYHT are the representative works of appropriate technology. They are not easy to duplicate in modern event industries. However, using a comprehensive range of measures, mainly high strength and light materials, ingenious and complex in design and supplemented by advanced prefabricate technology and innovative structural theory; it can be asserted that the kit-of-parts structures will completely replace the conventional type of event building.
CHAPTER 8 CONSPECTUS OF PREFABRICATED BUILDINGS WITH KOP STRUCTURES

It is always good to draw lessons from history. Today, with the globalization of the world economy many social, economic and technical problems that are in conflict with environmental preservation have been raised. As a result people often think that the earth is sick. Part of this sickness is related to the housing conditions of many people in the world, especially in its ever growing cities. Under these circumstances, is it possible to find a remedy for solving today’s housing problems that draw inspiration from Gropius and Wachsmann’s lifelong involvement with prefabrication?

Ever since industrialisation, the concept of the industrial production of houses has been seen by architects as a highly innovative step representative of the “house of the future”. As Viennese architect, Alfred Schmid concluded, the factory-made house must succeed, because of its economical cost, its speed and ease of erection and its independence of the constraints of both the traditional labor force and the vagaries of the weather.\textsuperscript{326} As an example of this approach, at the end of 1941, Gropius and Wachsmann’s ambitious plan for such a house was started with US government support. A highly automated housing plant and some elaborate corporate structures were set up in the US. Some houses were actually produced and sold but the dream was never realised to the extent that the designers had hoped. However, Gropius’s and Wachsmann’s rich exploration of the field covered the fundamentals of the factory-made house, and it is still possible to profit from their experience.

There is no doubt that the machine can provide people with mass-produced products that are cheaper than those manufactured by hand. However, when it comes to mass producing houses it is hard to build the house in the factory and ship it any distance fully assembled to site. Thus the mass production of houses has tended to be associated with some system of prefabrication, so that the parts are made in the factory, shipped to site and the house then assembled in situ from the components. The problem with prefabrication is that it has its virtues and its drawbacks. Each system could generate thousands of potential dwellings but these would all look very similar. Because the costs of tooling up to produce houses in the factory are also high there is the economic need to produce considerable numbers of the same design. This has meant that the prefabrication and industrialization of housing is associated with times of huge demand, such as times of war or natural disasters. For example, in the

period following the October 2004 earthquakes in Japan, prefabricated homes manufactured by Canadian industries were of vital importance for the people struggling with the aftermath in northwestern Japan. Almost every worker in the Canadian factories involved had to work on the nightshift, and the price for a single home soared from 80 thousand to 130-160 thousand US dollars during this time. However, six months later, when the earthquake threat had gone, most factories were shut down for a couple of week’s holiday due to lack of orders. This circumstance shows that growth in house manufacture was stimulated by market needs, and these market needs resulted from a temporary event. This is not the way to establish a successful prefabrication or industrialization housing industry. What the latter need is a regular market.

That said, the application of an industrialised strategy for the fabrication of the total dwelling does have obvious advantages not only in reducing the cost structure but also in achieving a uniformity of design and quality. However, because the ultimate goal is the integration of art into the life of man, houses cannot be produced in the exactly same way as Ford mass-produces cars. The pursuit of a manifold beauty is always a basic instinct of human beings. Although, the lowering of costs and improving quality in order to build cheaper, better, more attractive dwellings is still the basic principle of prefabrication, due to the evolution and physical advance of industrialised systems, especially the introduction of computer controlled manufacture, today’s architectural prefabrication has many more possibilities. Potentially, modern prefabrication has moved beyond saving money and time on a project. It is a solution which can solve the problems of the most complicated structural requirements, such as exhibition halls, sports arenas and convention centers for temporary, movable and changeable usage.

Nowadays advanced technology and materials can offer every kind of possibility for building almost every facility that people require. Architectural professionals are obliged to keep in line with this tendency so as to create designs that are aesthetically pleasing and that will also stand the test of time. However, it is necessary to pay special attention to the ecological environment as part of the sustainability of the human species. Because of the limitations of global resources, it is time for the exponents of contemporary architecture to use their expertise to adopt less-energy consuming methods.

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Footnote: 327 Combination of all kinds of trade information including Trading Post, west Canada version of Ming Pao newspaper and World Journal published in Vancouver, BC Canada.
than in the recent past. Land resources are the most important as ultimately land has to supply all human needs on a sustainable basis. If land is squandered the future of the human species is threatened.

As part of the husbanding of land, the ultimate goal of this research is to find a suitable solution for the problem of demountable exhibition building design. The fundamental aim is that the components used for these temporary events will be recycled and their resources reused once their purpose has been fulfilled. That means the system is not only for one event but can be changeable for many occasions depending on different uses. The prefabricated house by Gropius and Wachsmann has incorporated this concept of the standardization of parts that can be arranged to produce an infinite variety of whole structures. This will be the model for this present research and the literature review of this area as presented below.

8-1 A Brief History of Prefabricated Building

Although the prefabricating of parts of buildings is a medieval idea, with many timber and stone structures prefabricated in yards, marked, and then erected on site, modern prefabrication history could be thought of as going back to the 17th century in America. The early founders of the New World used prefabricated building parts consisting of wooden frames to build their houses in a very severe and tough environment. Since this early stage, the business of prefabricated, demountable buildings has been a highly commercialised trade in North America, the outputs of which are mainly used for construction sheds, warehouses and other temporary activities which only require a low level of usage. Hitherto, in projects like the TVA, North America have led world research into demountable
buildings,\textsuperscript{328} and the results have had influence around the globe.\textsuperscript{329} However, current research regarding prefabricated and demountable buildings is now sparse. This phenomenon is probably related to the modern quest for majestic buildings for perpetuity and may be why research in this area is not main stream at many schools of architecture and design.

In Europe the modern notion of prefabricated buildings made progress during the time of the Industrial Revolution at the end of 18\textsuperscript{th} century.\textsuperscript{330} With the appearance of new craftsmanship and materials, the way of prefabrication speeded up developments of industrialized building. The real decisive reason for this approach to building to be widely launched in many places, was given by the shortage of labour and construction materials after World War II, when houses, schools and even commercial buildings were prefabricated.\textsuperscript{331}

### 8-2 Mobile Buildings

Mobile buildings were marketed primarily to people whose lifestyle required mobility and were derived from the travel trailer or caravan. These were developed and became popular at the beginning of the 1950s. They are more frequently called manufactured buildings and originally were usually about 2.44 metres (8 feet) in width so they were easy to transport on the roads. Later models were much wider, with some models being up to 5.49 metres (18 feet) wide. The term ‘manufactured building’ is used to describe mobile buildings built before the US Department of Housing and Urban Development (HUD) code came into being on June 15, 1976. The HUD code is the only national housing code in the USA. It is also unique in that the code pre-empts all state and local codes. In doing so, it makes it possible for manufacturers of HUD code housing to ship their products to different states and not be concerned about the different requirements in different local housing codes. As a result, a few manufacturers with many plants ship homes to virtually every state in the US. There were nearly 300 plants producing manufactured housing in the United States in 2001.

An overwhelming majority of mobile buildings are now for residential use, so mobile homes can be thought of as the alternative name for mobile buildings. Few mobile homes today are really mobile.

\textsuperscript{328}Huxley J, 1943, \textit{TVA Adventure in Planning}, The Architectural Press, London

\textsuperscript{329}Casson, H, 1946, \textit{Homes by the Million}, Penguin Books, Middlesex


Most of these units are set on some type of foundation or pad in a mobile-home parking ground and are never moved. Some of these homes are quite spacious, but construction is generally less sturdy than in a traditional home. However, they offer a relatively low-price option for someone who wants to own a home.

Over 8 million families were housed in manufactured homes\textsuperscript{332} in 2001, and all such households at that time numbered 105,480,101.\textsuperscript{333} So, in other words, almost 8% of American households lived in mobile homes. Taking a closer look at these statistics, the fact comes out that between 2.5 and 3 million of the 8 million families are households headed by a person over 60 years of age. This fact suggests that mobile housing serves many low and moderate income households because of its lower price than other home ownership options. Mobile housing in the US home market represents over twenty percent of the annual housing production rate even with its relatively simple and crude function and appearance. Most mobile homes are purchased with a personal loan (like automobiles) rather than a mortgage loan.

Although it is commonly considered that the HUD code governs the construction of mobile buildings, these homes have actually only been built to industry standards which were voluntary. As such, the quality of such homes differs between manufacturers. Currently in the United States, each home or segment of a home is labelled with a red tag which is the manufacturer's guarantee that the home was built to conform to the HUD code. The materials for manufactured homes are the same as site constructed homes, but they are built on a non-removable steel chassis and transported to the building site on their own wheels.

The caravan is a small trailer in which people can live and travel. Recently a London-based architectural office adapted the idea to create a prototype in development, which is called Orb, being a modern version of a mobile building as well as a travel trailer (Fig.8-3).

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{Fig8-2}
\caption{Home of the 1960s-70s: twelve by sixty feet (Image by M. Thivierge)}
\end{figure}

\textsuperscript{332}Robert W. Wilden, \textit{Manufactured Housing and its Impact on Seniors}, prepared for the Commission on Affordable Housing and Health Facility Needs for Seniors in the 21\textsuperscript{st} Century, as a part of final report to Congress on June 28, 2002.

\textsuperscript{333}U.S. Census Bureau, \textit{Census 2000}, special tabulation, internet release date: September 7, 2001
Compared with other comparable mobile homes Orb is built to a significantly higher standard. It is manufactured with marine technology, giving intrinsic strength with lightweight material, making it easy to transport. Orb’s oval shape and generous glazing provide not only a glorious sense of space and light but are combined with insulation in the solid wall skin. The Orb has been designed to sleep seven people comfortably with flexible modular furniture that can be easily cleaned, removed or refitted within a shell that is guaranteed to last. The Orb’s adjustable legs and removable wheels make siting and leveling quite convenient. The design of the internal chassis will prevent corrosion or decay to the substructure as it is completely encased by the unit. This gives the Orb an advanced high-tech appearance, more akin to that of a yacht than a caravan.

The Orb represents a tendency towards more use of advanced technology in the mobile building industries in the UK and Europe. The Orb’s standard size is 12 m x 4 m which is exactly the maximum size of static caravans. In the UK mobile homes consist of touring caravans, static caravans and motorhomes. Being towed behind a car to a special site and parked, a touring caravan often stays there for only a brief period. Normally the size of touring caravans is not larger than 3 x 5 m and can have 1 or 2 axles (2 or 4 wheels respectively). For static caravans, the size can be as much as 12 m x 4 m, meaning they are too large to tow. Therefore they are transported on the road using large flatbed trucks. A static caravan will normally stay on a single plot for many years, and is fitted with many of the modern conveniences normally found in a home (Fig.8-4). This UK caravan-style of mobile home is classified as a transportable building: it is ready to move into
within days and can be situated in places that a conventional home cannot because of its wheels, but it is far from being a trailer.334

Motorhomes, actually big automobiles, are similar in size to touring caravans but with one main difference: they have engines and do not need to be towed. Motorhomes can be equipped with many modern conveniences such as showers and full-sized cookers. Motorhomes are, to all intents and purposes, full touring caravans that can be driven from site to site. Manufactured homes are currently built to conform to the modern highly motorized way of living, rather than conforming to a life style where manpower or even animal-drawn carts are still the usual medium. From this point of view it will not be difficult to understand why mobile homes or work/tool shop (Fig.8-5) are still popular in the USA and UK, with some low-end homes being the solution for low and moderate income households. This kind of pseudo-nomadic life style is particular to these countries and its appearance and existence has its own rationality and inevitable certainty. Furthermore its development would not have been possible without the very high rate of private car ownership, very convenient highway system, and mechanised housing manufacturing industry, and it has also been aided by a complete system of legislation and management.

8-3 Modular Building - Change in Design with Increasing Demand

The earliest embryo design for a modular home, which was a pre-cut home also known as a kit home or Factory Built Housing:

...dates as far back as the early 1900s with the advent of the Sears & Roebuck homes that were purchased out of a catalogue and shipped to the customer. Customers would choose their design and several weeks later their new home (in 30,000 pieces) arrived via railcar. This was the

334http://www.theorb.biz/homePage.asp
beginning of the factory made concept where components of a home would be constructed off site and shipped to a building location.\textsuperscript{335}

After World War II industrial production quickly switched over to providing consumer products for growing needs. This included manufacturing housing, although initially prefabricated housing was seen as a way of providing housing in times of shortage of traditional materials and craftsmen. It was also seen as a way of keeping large scale industries in work after the war in switching from making aero planes and tanks to houses.\textsuperscript{336} As an example, over one thousand prefabricated homes were erected in Belle Vale, Liverpool, between the years 1945-1947 in order to provide affordable rented accommodation for people whose homes were destroyed in bombing raids on the city during World War II, making it one of the largest ‘Prefab’ communities in the UK.\textsuperscript{337}

Apart from World War II, the manufactured housing industry also received a dramatic increase in popularity as American became more affluent. The 1960s and early 1970s saw industries start to create a “modular” home product. This was basically a site built or “stick built” home (Fig.8-6) completed in two units, transported to the building site on flat bed frames and then erected onto a permanent foundation. During this period the style of home was typically limited to a ranch home and normally consisted of a single floor and two or three bedrooms.

Modular and manufactured construction both grew quite substantially from the late 1970s to the early 1980s. At this time, conventional builders struggled to keep up with demand for stick-built (precut and site-built) homes.\textsuperscript{338} As a result, factory built homes began to emerge in the marketplace. Design styles of modular homes moved from the typical ranch style to a more complex

\begin{itemize}
\item \textsuperscript{336}Brenda Vale (1995), Prefabs; A history of the UK Temporary Housing Programme, Taylor & Francis
\item \textsuperscript{337}Port Cities: Post War housing in Liverpool, E. Chambré Hardman Archive, retrieved 13 August 2007
\item \textsuperscript{338}A house or other structure built piece-by-piece at the construction site, as opposed to factory-built. It is a North American term. Homes that are custom-designed or built according to stock plans are considered stick-built so long as they are constructed on-site.
\end{itemize}
split level, such as the Cape Cod 1½ storey house, and two-storey homes (Fig.8-7). Commercial applications of modular construction including motels, offices and school classrooms also began to emerge. Multiple roof lines, customised exteriors and more contemporary designs began to appear.

Conventional stick-built homes were normally made of 2 x 6 (38 x 140mm) or 2 x 4 (38 x 89mm) lightweight wood frames for the walls and roof. The wall and roof surfaces were then covered with structural OSB or Plywood sheathing to supply the overall rigidity for the structure. These wood frame systems could be used for single family villas as well as condos and commercial buildings up to four storeys high. In competition with the conventional approach, during the mid to late 1990s growth of manufactured homes continued as the industry began to build larger and more complex homes.

Modular manufacturers attempted to build more sophisticated two-storey, multi-family dwellings and customized luxury homes.

From this time on many high-end homes have come out of modular manufacturers, costing more than US$500,000, and only including the unfinished units from the plant to be finished and fitted out on site. This is in absolute contrast to consumer traditional mindsets about modular homes, which see them as cheap and repetitive. These kinds of luxury homes are normally priced from $200 to $300 sq ft ($2000-3000 per m²) and are designed in a modern style in the US housing market. Some even have solar panels or wind generators added to achieve green credentials. The prefab modular components come pre-wired and pre-plumbed. This is evidence that the industry has begun to mature and be recognized as a viable option that in many cases is preferable to traditional homes. By 2000, modular building systems have seen an increase in production due to the favourable building conditions throughout North America. As the demand for skilled labour and quality materials increases, modular construction remains an option for those seeking top quality constructions because of the factory finishes at competitive prices.

Modular building is a method of constructing buildings and equipment. It means building in certain shapes that can be repeated as required, called modules or units, which are constructed off-site, transported to a building lot, and assembled into a finished building. All the materials used in modern modular houses in the USA are almost the same as would be found in a conventional stick-built building. With more advanced technology and equipment added into the production line of the module,
for example all kinds of adhesives and clamping apparatus, some traditional acts of craftsmanship such as making mortise and tenon joints are fading out. The most obvious thing about a modular building is that it is made in a well-equipped plant with advanced technology designed to build good-quality buildings. Another significant and identifiable thing about a modular building when compared with a conventional building is the result when standardized modules are widely used. A module is an element that expresses the proportions of the entire structure. It can range from a simple brick to a large cube up to a spacious module. Both modular and prefabricated characteristics are interrelated. Because of the quantity of repetitive dimensional or functional units they must be made in a factory to meet the requirements for quality and time. One of the widely admitted definitions by the industries is that commercial modular construction means that between 60-95% of the whole is completed at the plant and then delivered to the site for final assembly. According to the recently published report of the Modular Building Institute (MBI), 2006 was a very significant year for commercial modular construction. The report is composed of data from a variety of sources including a prepared survey questionnaire sent to members and non-members in the industry, public SEC filings, and direct communication with company leaders. Many companies reported double digit revenue growth for the year, fuelled by strong construction activity in the education, health care and government markets. Additionally, the market was (and continues to be) very active in certain geographic areas such as the western provinces of Canada and surrounding areas, while traditional markets like California, Florida, Texas, and the Mid Atlantic United States remained solid. Following overall economic trends, the central region of the United States continued to lag behind other areas.339

Some special attention has to be paid to western Canada, which is a traditional hub of the timber industry. Once there were huge piles of pine, spruce, fir, cedar, and hemlock shipped to the US, Asia, and even to Europe from here every year. The local stick-built (site-built) homes market was dominated by a 2 x 8 (38 x 200mm) frame system at that time. Due to considerations of environmental protection and the soaring price of timber, the government authority started to forbid the exportation of raw timber in the 1990s. With such a background the 2 x 4 frame system came into popular use through the North America Free Trade Agreement (NAFTA) area. Since 2000, Western Canada has been experiencing significant growth of the modular industry. Because of the 2010 Winter Olympic

Games in Vancouver and the swelling ranks of people arriving in Western Canada’s premier oil industry region to work on projects, most manufacturers of modular buildings have extended beyond portable classrooms and construction site offices to large camps in the oil sands. In terms of construction, British Columbia and Alberta are the two busiest regions in North America. Most companies have reported soaring increases of approximately 300% over the past two years in terms of volume.

Fig. 8-8 left, Japanese carpenters working on a traditional 2 x 4 frame structure. Fig. 8-9 right, SIPs in harsh climate - Antarctic, Source: http://www.sips.org/

Although pre-cut homes can be found in some construction chain stores such as Home Depot who trade in the west coast of North America, it is not easy for an ordinary family to build a home in such way. The most important thing is that even though more elaborate kits are offered it is still difficult to ensure adequate quality that meets modern life requirements. This is based on two reasons. The first is the difficulty an ordinary home owner has with the construction work conditions, as getting into the construction industry has a minimum requirement of a community college certificate in lieu of 2 or 3 year’s carpentry apprentice training in North America. The second reason is that despite the factory production of components, manually assembled houses cannot be guaranteed because of the complexity of today’s homes. As a result, panelized homes, including those made of Structural Insulated Panels (SIPs), are taking the place of pre-cut homes. These are buildings made of factory-built walls that are typically 8 feet (2.4m) tall and 4-40 feet (1.2-12m) long. Used in floors, walls, and roofs for residential and light commercial buildings, SIPs are high performance building panels. The panels are typically made by sandwiching a core of rigid foam plastic insulation between two structural skins of Oriented Strand Board (OSB). In the early years most of these were just plain

panels without any sophisticated techniques attached. Now most panelised systems include plumbing and wiring and have insulation already installed, while others include only the framing and sheathing. The former is commonly called a closed-panel system and latter is an open-panel system.

With the depletion of the planet's resources and the rising cost of energy, being "green" has gained an increased importance in the way houses are constructed. The environmental benefits of a green lifestyle can be incorporated into the design of houses and other buildings through the use of SIPS. The SIP building envelope is on average 15 times tighter than conventional framing. The superior insulating qualities of SIPS allow for reduced heating and ventilating equipment in houses and up to 50% annual savings on energy are possible when the panels are combined with other energy efficient technologies. The use of petroleum to make foam products such as the polyurethane insulation used in SIPS panels may represent the resource's highest and best use, by drastically reducing the long-term need to consume fossil fuels for heating and cooling energy.

Prefabricated panels can be assembled in a fraction of the time taken for stick framing with less skilled labour involved. SIPS also reduce the amount of jobsite waste going to landfill. Their performance is so good they have even received government endorsement. The United States Energy Policy Act was signed in 2005 giving financial incentives to residential contractors and commercial building owners that build energy efficient homes and buildings; therefore, buying and building with SIPS qualify for many tax rebates and incentives, Energy Efficient Mortgages for homeowners and environmental points towards certifications.

Modular commercial buildings, as with any other building type, come with pros and cons. The advantages of modular commercial buildings could be as outlined below.

a) Cost Saving - Modular building can offer a cost saving in excess of 50% compared to conventional construction methods. The savings basically come from assembly line efficiency and lower maintenance fees later on.

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342 Premier Building Systems, SIPS Tax Credits & Environmental Points, 4609 70th Avenue East, Fife, Washington, USA http://www.premiersips.com/product-resources/credits-points/
b) Time Savings - Assembly line construction also decreases the total fabrication time. Once the modules are completed and transported to the building site, the “Off-site Modular builds usually only require mechanical handling for the first day or two…”344 Units are typically constructed in an enclosed facility; therefore weather is not a factor in the construction time line.

c) Portability - Modular buildings are considered permanent structures but if necessary the large modules can be disassembled. Some modular manufacturers will rent out modular buildings “to capture both seasonal and post-recession demand for modular buildings.”345 Material delivery fees are also eliminated because an ample amount of material will always be available at the facility, as opposed to being delivered in limited quantities to the job site, thereby nearly eliminating construction delays.

Fig.8-10 left, modular construction is the cost effective, sustainable solution but the aesthetics can be poor. Source: /www.facilitymanagement.com. Fig.8-11 right, Grind Injection Facility - Arco - Alpine Development - Alpine Field, North Slope, Alaska, source: http://www.eeis.net/servlet/content/Portfolio.html

The disadvantages of modular commercial buildings could be as shown below.

a) Limited Customization - Modular buildings do not, as one commercial operator stated, “have no design limitations they can be any shape or size” as they can only be customized to a certain extent. However, if the client and designer want a totally original appearance modular buildings will not be able to deliver this. Most systems follow a variety of designs that can be changed and customized. But these designs do have limits with regard to dramatic changes to the shape or look (Fig.8-10), as because of the saving of time and cost for mass production, they are designed to be as simple, common and regularly shaped as possible in most cases.

344The advantages of using Conventional Modular and Off-site Modular, 19 Jan 2011
cabinco.co.uk/the-advantages-of-using-conventional-modular-and-off-site-modular-construction-for-school-building-projects/
345Modular Building News, www.greenbuildingdigest.net/modular-building.html
b) Limited Service Area - Since the modules are constructed in a factory and then shipped to the building site, the building site needs to be reasonably close to the factory. Considering the shipping costs grow uneconomical for long distances, “Not many home-builders buy packages from a factory more than 300 miles away.”\textsuperscript{346} The costs and transportation difficulties greatly increase for building sites farther than 300 miles from the factory.

Modular buildings tend to either be used for long-term temporary or permanent facilities. Such uses include construction camps, schools and classrooms, civilian and military housing needs, and industrial facilities. Modular buildings are a perfect solution in remote and rural areas where conventional construction may not be reasonable or even possible. One example would be the Grind Injection Facility, Alpine Development, Alpine Field, North Slope, Alaska (Fig.8-11). The Grind and Injection Facility consisted of eleven trailer mounted modules. Other uses have also been found for modular buildings including fast food restaurants and cruise ship interiors.

It seems that modular buildings are becoming increasingly popular not only with those in the market to buy a new home but also with more and more commercial customers.\textsuperscript{347} Another exciting thing is that almost every university architectural school in North America is now starting to pay more attention to various aspects of off-site residential fabrication. The eight designs (Fig.8-13) below are student work and represent seven different universities. Since the university is an original resource for examining and broadcasting new ideas and thoughts, this may push more people to accept off-site

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{Fig8-12.png}
\caption{Major Markets Shares of USA Modular Manufacture. Source: www.mbinet.org (retrieved in Mar. 2008)}
\end{figure}

\textsuperscript{346}Ingersoll, J. PM's Complete Guide to Prefabricated Housing, \textit{Popular Mechanics}, 2/1984

\textsuperscript{347}MBI/Baird survey Nonresidential modular manufacturing up 9\%, \textit{Modular Advantage}, September 2007
residential fabrication. Only when they can be seen more frequently in the public building sector (Fig.8-12) will it be possible to say that modular buildings have equal status with site built buildings.

Fig.8-13 modular building designs. Source: http://fabprefab.com/fabfiles/fabschool.htm

8-4 Demountable Buildings

When talking about demountable building, generally what is meant is a building designed and built to be movable. Instead of being permanently located, such a building is more often used temporarily and taken away later. The caravan as discussed above would fall into this category. From the viewpoint of transportation the building can be carried whole (like the caravan) or disassembled and container-packed and moved from site using truck, ship, or train and slung on and off the transport by crane, or even by a hand if the building is small. Essentially, the definition of a demountable building relates to its physical status, with prefabricated pieces or elements of it assembled on site, and vice versa when it is dismantled before being moved from site to site. There are overlaps between modular and demountable building because most modular buildings are demountable as well, and to make a building demountable means designing it to make it modular with the means of transportation. The divisions between the two categories are not sharply marked. However, there are some indications that make a division possible. Physical status, such as the size and assembly method of units, will aid the definition. As stated above with reference to moving a whole building, such a building is not likely to be modular. On the other hand a building that takes to pieces and is packed into a container for re-use could easily be modular.

The development of demountable building appears rather slow in comparison with modular building, although the idea of being demountable stems from ancient times. One of the ancient Chinese
craftsmen’s contributions to demountable building was that they used the idea of an assembly procedure for the Repair Techniques of Wooden Frames of Ancient Buildings,\textsuperscript{348} as recorded by the renowned Chinese architect couple, Mr. Liang, Sicheng (1901-1972) and Mrs Lin, Huiyin (1904-1955).\textsuperscript{349} Once during one of their research trips in the countryside of Shanxi province they found there was a continuous numerical series written in black ink stone behind or underneath each wooden element of a thousand year old temple. The numerical order was actually the assembly sequence. For thousands of years yurts and other tents, representing perhaps the most popular application of demountable building, were used for a nomadic lifestyle and for military functions. Later the Crystal Palace, assumed to be the largest demountable building in world architectural history, was erected for the Great Exhibition of 1851. Although it was a very special product created under unusual circumstances it was an extraordinary achievement. Looking at the fact sheet of the Crystal Palace it took 4,500 tons of iron, 60,000 cubic feet of timber and over 293,000 panes of glass, for 770,000 sq ft. of floor area but it took 2,000 men just eight months to build.\textsuperscript{350} Such a large scale temporary building with so short a time frame for its building would even now be a real challenge to any architect. Critically for this research, after the exhibition in Hyde Park the building was dismantled and re-erected in Sydenham, south London, where it remained in use until it burned down in 1936.

From the period of modern architecture, some embryonic forms of demountable thinking were demonstrated by the Dutch architect Gerrit Rietveld’s 1924 house for Truus Schröder-Schräder. In this house a system of sliding and folding walls and surfaces created dynamic, changeable living spaces.\textsuperscript{351} However, this is an example of moveable architecture rather than demountable building.

At the present time things are quite different in Europe, as 80% of the total population, about 250 million people, lives in urban areas. Half of the total consumption of energy is spent operating and constructing buildings. It has been estimated that about half the destruction of the natural European environment has been caused by engineering and construction projects there. People are being

\textsuperscript{348} Text proper in Chinese: 古建筑梁架维修技术

\textsuperscript{349} Both were professors of Architecture, and the founders of Chinese education in modern architecture and the Department of Architecture at Tsinghua University.


\textsuperscript{351} Kronenburg, Robert (2007), Flexible: Architecture that Responds to Change, Laurence King.
threatened by a worsening environment. Even though modern European prefabricated buildings are considered to be soulless boxes which only serve as mobile site huts and classrooms, today certain scholars are involved in this type of research there. In Belgium, K.U. Leuven together with two partners, the Belgian Building Research Institute (BBRI), and the Belgian Federation of the concrete industry (FEBE), are working on a four-year (2004-2008) joint venture research project for industrial, flexible and demountable buildings (IFD). The aim of this research, based on the need for adaptable and affordable buildings, is to stimulate the sector making prefabricated concrete elements to develop new products that allow for efficient industrial production, a variety of end products, adaptable buildings, and demountable buildings. The project has funding from Science and Technology in Flanders (IWT-Flanders).

England, as one of the earliest countries involved in research into prefabricated building systems, has completed research work that sounds both more mature and practical. Under the Building Regulations Division, Department of the Environment, Transport and the Regions, the Second Edition of *Temporary Demountable Structures - Guidance on Design, Procurement and Use*, was published in March 1999. The report provides comprehensive guidance on the use of temporary demountable structures such as grandstands, large tents, stage stands, and panelised building systems. It offers professional references for event organizers, venue owners, local authorities, contractors and suppliers of demountable structures. The report is also meant to serve as an advisory document for designers of temporary structures. It also provides a summary of applications of demountable structures. The related research was undertaken in universities and leading architectural firms. A demountable canopy for temporary grandstands, based on concepts developed at the University of Dundee during the late 1990s, has been successfully built. The canopy represents the great progress in the industry in the last 20 years. The School of the Built Environment, at the University of Nottingham, is also a leading centre in the field of renewable technology related to temporary structures especially in space structures and textile architecture. Academic staffs at both the Environment and Structures Group and the Design Research Group at the University of Sheffield have been concerned with issues relating to the integration of structures with architectural design and with a new prefabricated eco-classroom design. Among them Dr. O. Popovic’s recent book, *Reciprocal Frame Architecture*,352 explores the

principles of the three dimensional assembly of mutually supporting beams through both ancient and modern case studies. The book offers inspiration for the development of demountable building.

In the Netherlands, practical applications of prefabrication can be dated to the 1960s. Currently, emphasis is on demounting ability. One of the big issues in the housing stock in the Netherlands is the fact that in the 1960s a lot of four-storey buildings were built that are now no longer appropriate for the current standards. The normal way of upgrading these buildings is to demolish them completely and start again. This approach causes a big environmental problem, as the waste has to be dumped somewhere. A more environmentally sound approach is to demolish only that part of the building that is above the foundation. The foundation can then be used again to support a new and more durable building. Apart from this endeavour there have been several instructive pilot projects of demountable buildings such as The Children’s Art Gallery in Rotterdam, which was erected by Dutch architects during the late 1990s. A number of groups are very actively involved in research into durable building. Durable buildings are characterized by maintaining a high level of functionality while having a low impact on the environment during their whole lifespan. This set of characteristics is related to the subject of IFD. Up to now, several dozen IFD buildings have been built in the Netherlands, most of them office related, and like the research in Belgium, they get full support from the Dutch government.

There is no doubt that the research centre for IFD is in Europe. Besides the above mentioned countries, the principles and technology of IFD are being used in both France and Italy. France has a long tradition in prefabrication building systems, such as the TRACOBA and Camus building systems for housing. Italy’s precast industry also has a good reputation. However, when talking about Europe, Germany must also not be ignored. Although individual enterprises in Germany have launched demountable buildings, the development of demountable technology has a potential market demand there, especially for demountable exhibition buildings. As a country with a world leading exhibition and convention sector, German’s excellent industry and infrastructure will be brought to the problem of designing such structures.

Reviewing current research literature regarding demountable buildings, there is no finding which can fully answer the question about the sustainability of a system of reusable components, not to mention specific research related to demountable exhibition building systems. As to the application of demountable exhibition buildings there have been a couple of examples. One is a low energy
demountable exhibition hall designed by a team, led by London-based Robert Webb Associates, to be used for shows on sustainability. The timber-arched structure has a total area of 1500 sq.m. It uses minimal embodied energy and can be packed up in about a week for transport. It is even equipped with a range of renewable-energy devices including photovoltaic panels and wind turbines. Its monotonous arched shape may be a problem if it becomes the prevailing style of exhibition halls. Another example is the Swiss Pavilion of Hannover Expo 2000, as discussed earlier. This pavilion was made of pine without one nail and has been removed and reinstalled at another location. The design was good, but it was a reusable building only. It cannot be called a system.

8-4-1 Reusable/relocatable buildings

As one of the most popular applications of the concept of demountable building, the reusable building is generally designed and built for multi-functions and to be capable of being dismantled then assembled to the same plan and shape, and used again but in a different location. Such buildings have been widely used as emergency shelters, work sheds and many other low-end purposes. But by combining advanced technology and new materials, a new generation of reusable building is coming with a completely new appearance. One of most recent examples is the design proposal for the 2012 Olympic Stadium in London. The British design firm, HOK Sport and architect Peter Cook of HOK, have developed the plans for a demountable 80,000-seat stadium for London’s 2012 Olympic Games. Ignoring all criticism, the design is a comprehensive application of real demountable building. It was reported that the future demountable stadium will have a cable-supported roof with a diameter of 92 feet (28m).

Most of the services for catering, toilets, and retail stalls will be located in removable pods on a 360° ground level concourse outside the main stadium bowl. Ignoring some critics of the appearance of the stadium its sustainable quality seems very good. The building can be dismantled after the Games and moved from its site at the southern end of the Olympic Park in East London’s Lower Lea Valley to serve as a sports venue elsewhere. Construction started in April 2008, and the stadium is now almost finished (at the time of writing this part of the thesis). It marks one of the most significant advances and a breakthrough in modern architecture.

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353 Architectural Record, Dec 2007
8-4-2 Kit-of-parts/adaptable buildings

A kit-of-parts originally refers to equipment or a mechanism consisting of a set of hardware or tools for a specified purpose. Now it is more popularly associated with the industrialization or prefabrication of the components of a building system.

Kit-of-parts construction is a special subset of prefabrication that not only attempts to achieve flexibility in assembly and efficiency in manufacture, but also by definition requires a capacity for demount ability, disassembly, and reuse. Kit-of-parts structures can be assembled and taken apart in a variety of ways like a construction toy. In architecture a kit-of-parts is one form of building system. Christopher Alexander once said “…a generating system is not a view of a single theory. It is a kit of parts with rules about the way these parts may be combined.”

Early forms of building systems that used the idea of a kit-of-parts are cast iron churches, houses for early colonial development and hospitals for the Crimean War. After this early period, however, the idea of a kit-of-parts remained undeveloped. However, Charles and Ray Eames’s catalogue approach to housing design in the 1950s changed the situation completely. The idea of a kit-of-parts became important for architectural professionals and thus spawned a whole generation of consortia building systems throughout the world. Some hybrid buildings have called their systems a kit-of-parts without this being strictly accurate. In the strict sense of the word, the kit-of-parts is an open system which


355 Christopher Alexander, Systems Generating Systems, 1968
must function with interchangeable as well as some vital fixed components. The interchangeable component is the key element which makes the system adaptable. Another important difference between a reusable building and a kit-of-parts/adaptable building is the variability in responding to the environment. The reusable building is almost a constant relative to the environment. In this approach one standard design is good for everywhere. However, each site needs its own blend of the architectural elements that respond to the natural conditions and the materials available. The kit-of-parts/adaptable building can only conditionally satisfy these demands. The flexibility given by interchangeable components means the building can be adjusted, redesigned or reconfigured to fit most different sites and conditions. The final result may not be as good as a custom-designed building, but will be better than a standardised reused building. For a better understanding of the kit-of-parts approach, the following prefabricated holiday home, the iPad, is a good example of the type. It was developed by Hodgskin and his partner Russell Cannons at Architex.

![iPad prefabricated holiday home](http://www.ipad.net.nz/)

This kitset building is a 40sqm studio that is based on a standard 1.2 metre panel unit, with a clip-on service area comprising the kitchen and bathroom. The room can be divided into two spaces by a fold-down double bed divider. The plan is very flexible as it offers multi-combination plans for
different options, but it cannot be called a kit-of-parts or adaptable system, because there is no interchangeable component, as all options are based on the same plan dimensions. It is a reusable building.

Another example is the Swiss Pavilion of Hannover Expo 2000 which drew upon the Swiss tradition of solid log buildings, found in their Alpine chalets. This pavilion was made of pine without one nail (Fig.8-18) and had been removed and reinstalled at another location. The building was planned from the design stage to be dismantled and the materials reused. In 2002 they were recycled to produce a large wooden sphere known as *Le Palais de l'Equilibre* for Switzerland's Expo 2002 in Neuchatel. This imposing structure housed a presentation illustrating the fragile balance between the world's economy, society, and environment. Wood was cleverly crafted to provide a geometric sun shield around the outside facade of the sphere. One of the initial ideas of this building, apart from the recycling of wood, was that the place should be a sort of 'rest house', where people could relax in the small internal piazzas to which the maze (without too much difficulty) delivers them. People could also pause in the strange black oval three-storey elements which house the service parts of the pavilion, and have quiet spaces for sitting on top. Without being overt, in this building there is again a trace of one of the essences of Switzerland, the tradition of efficient hospitality.

![Image](http://eng.archinform.net/projekte/8423.htm)

**Fig.8-18** left, the Swiss Pavilion of Hannover Expo 2000, sources: http://eng.archinform.net/projekte/8423.htm.

**Fig.8-19** right, *Le Palais de l'Equilibre* for Switzerland's Expo 2002, source: http://www.magiccarpetjournals.com/

### 8-5 The Significances of Kit-of-Parts Structures

Although it is very hard to find a typical precedent of a kit-of-parts or adaptable system, this approach has obvious advantages over other kinds of prefabricated building especially regarding land saving
and low construction waste. Such buildings could also be designed for low maintenance and zero environmental impact. This would make a significant contribution to sustainability.

The kit-of-parts represents a significant departure from the architect's traditional design and build system. Compared with the long history of conventional architecture, research into demountable buildings, especially for the kit-of-parts system is still in its infancy. The new technology and materials promoted in recent years along with the increase in people's environmental awareness have built a steady ground for a breakthrough for this building type.

8-6 Brief Summary of this Chapter

Prefabricated building is not just all of the components out of factory production, site assembled components, no wet field assembly construction, less noise, dust and garbage, less impact of climate, does not use clay brick, removable and recyclable, but it increased at a deeper level the building’s adaptability and growth ability, this is the quality of event building in the urban environment most looking forward to.

The structural adaptability of a big events building will reflect the characteristics of the industrial age, namely the structure will need to be rationalized and standardized to improve productivity, as well as attempting to reduce the demand for new materials through ensuring their flexible usage. The structure in a building for big event needs to create a form strongly capable of adaptation, responding to changing requirements in function. This can be shows in two aspects: having a structure that creates a free plan; and having a structure designed for easy alteration and expansion to meet the building’s future development. This kind of adaptability is inseparable from the technological development of large span structures. At the same time, the structure has to be standardization to the degree that the structural parts can be prefabricated and assembled, but also disassembled, thus making the structure fully versatile so it can be applied to different occasions.

Providing column-free apace with a large span makes the spatial layout very flexible. Often exposing the structure outside the building envelope can create such a space. For example, the IBM Sports Hall designed by Nicholas Grimshaw has an exo-skeleton of five trussed portal frames with an 18m span, which support the roof from above, thus forming a structure free internal space with strong flexibility. Having a free plan makes it possible to adjust internal building functions. For example, a variety of functions should be considered when designing a stadium, such as competitions, rallies, lectures,
exhibitions and concerts. A large span column-free space provides a wide range of possibilities for such multi-functional use. Large span structural adaptability also provides the opportunity for renovation and expansion during the life of a building. As Kenzo Tange has stated productivity keeps the building growing all the time within the surrounding life and the whole environment, referring to this as building

Structural variability is reflected in the number of structural units in a building. Kisho Kurokawa introduced a frame system in the design of his Expo’70 Takara Beautilion (see Fig. before), within which can be inserted functional ‘cabins’ prefabricated in a factory for accommodation or production, movement systems and mechanical equipment as needed. The idea of the organic growth of a building is reflected in such experiments.

Fig.8-20, the flexible Igus factory in Cologne designed by Nicholas Grimshaw

A group of High-Tech architects have used modern industrial technology to growth potential to building structure. For example, Nicholas Grimshaw found a way to combine the same structural units when designing the Igus factory in Germany (Fig.8-20). The roof is carried by two masts through cables. Offices and production service systems hang from the roof, and flexible pods for management and other functions supported by steel columns can be placed inside or outside and even combined together to form a bigger unit. Cladding is also designed to be removed and replaced by door and window units if necessary. Every single part of the whole construction is variable to adapt to different business needs. Norman Foster took the same approach in the design of the Renault distribution center, again separating the skin from the structure. The modular structural units ensure factory can extend at any time if needed. Meanwhile the structural units repeat to obtain a beautiful integral rhythm(Fig. 10-5).
CHAPTER 9  DEMOUNTABLE BUILDINGS IN MODERN SUSTAINABLE CITIES

9-1  Creating buildings which can change in time and place

As exhibition and events buildings change from being one-time use only to being designed for permanent use, or to be temporary facilities, this can be seen as an evolution of physical civilization. It is a logical result of progress both in technology and ideology as well as the inevitable response to the threatening problems of insufficient energy and resources. Building as a social product in the history of civilization, just like human society itself, is always changing and developing with the passage of time, thus reflecting the vicissitudes of society. Since buildings are from different times, corresponding with different natural conditions and social conditions, buildings will inevitably differ from each other. Different times produce different buildings which in turn adapt to and reflect different times. The basic element of time can be described as an event. According to the Theory of General Relativity, “time has no independent existence apart from the order of events by which we measure it.”

The only correct attitude towards building changing from time to time, which in fact is no different from other things, is actually embarking from “today.” This prepares the way for tomorrow’s needs and starts with today’s natural and social conditions, with the aim of solving the problems humanity is facing that need to be resolved today.

9-2  Approaches to a Harmonious Environment

Modern human beings are experiencing all kinds of unprecedented deterioration in global conditions: examples would be water shortages, global warming, species extinction, air pollution, and in terms of urbanisation, the Heat Island Effect and encroachment of development on farm land. All have put human future into a more precarious situation, which has given rise to thoughts of sustainable development and smart growth, especially in America. These ideas emphasize harmonious living with the environment, and advocate that the city landscape and construction must respect nature, human beings and the local spirit, through following a path of sustainable development which respects the natural laws and ecosystems.

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356 Lincoln Barnett (1952), The Universe and Dr. Einstein, New York: Mentor Books, p. 21-22
“Unity of heaven and human beings”\textsuperscript{358} has always been one of the core principles in Chinese traditional culture. Taoism highlighted the idea that the person reflects the earth, the earth reflects Heaven, Heaven reflects the way, and the way reflects its own nature.\textsuperscript{359} Confucianism emphasized that observing the laws of nature changed the timing for production and life, through paying attention to ethical relationships.\textsuperscript{360} If the BYHT is considered to be a regional unique cultural icon passing from generation to generation and a durable artefact, this Tibetan tradition contains the simple thought of harmoniously coexisting with nature in cruel conditions. This in turn shows that the Chinese ancients’ simple ideology of harmony, commitment and coexistence with nature can result in a type of development in which mankind unifies with nature, in other words this is sustainable development. From the final sense, to protect the environment and nature means to protect human beings. Planning is a basis and a means of guiding the reasonable development, construction and management of a city and it is the “head” of the process. Therefore, to ensure the sustainable development of a city, people must start from the head— from planning.

The first step in planning is that regional planning needs to be conducted in accordance with development demand and resource conditions. This means thinking about urban clusters or urban belts as whole rather than separate entities, thus guaranteeing that there can be resource sharing and mutual complementarities among cities. This avoids the situation of disordered development in which each city goes its own way, even to the point of hostile competition which will cause the pollution of water and land and the destruction of the environment and local ecology. With regard to each city’s planning, especially in the zoning of city functions, the goal should be to merge the modern civilization of a city in the natural environment with a reasonable layout of residential areas and the location of commercial and industrial areas, while fully protecting the original rivers, lakes, sea, mountains, parks, forests and trees, and merging these into the city's modern form in the natural environment. In terms of the new developments, an emphasis should be put on the integration of

\textsuperscript{358}Text proper in Chinese: 天人合一, Zhang, Zai (张载 1020-1077) of the Northern Song Dynasty (960-1127) was the person who made the earliest explicit statement of this idea. He was an important thinker in ancient China during the time of the Northern Song Dynasty. His works were highly regarded by the governments of both Ming and Qing Dynasties, as well as being the main content for the imperial civil examination.

\textsuperscript{359}Text proper in Chinese: “人法地,地法天,天法道,道法自然” from Lao-tzu's classic book on the Tao, the Chapter 25 of Tao-teChing.

\textsuperscript{360}Text proper in Chinese: “……观乎天文以察时变，观乎人文以化成天下.” from "Book of Changes " (《易经》中贲卦的彖辞). The contents of the Book of Changes include ancient Chinese divination and cosmological beliefs.
buildings and nature, with both evenly scattered, and well integrated with each other, and avoiding over intensiveness or over building. It is necessary to respect the feelings of people for nature, making full use of the original topography, terrain features and natural landscape, and abstaining from large scale digging and filling. It is also necessary to avoid the restitution of the natural scene with artificial beautification, so that the sustainable principle of architectural design can be realized through the integration of human beings, buildings, and nature. In construction and city planning, the natural features of the terrain should be protected, emphasizing the natural landscape, and making the most use of rich resources like the climate conditions, and local tree species and flowers and shrubs to construct a “green city.” In the final analysis, it is the land saving that counts in the inevitable choice between the man-made and natural diapason in the future.

9-3 A Circular Economy

As an effective way and important part of the strategy of sustainable development, the concept of circular economy is based on two ideas: the closing materials cycle economy; and the resources circulating economy.\(^{361}\) The germ of this idea can be traced back to the 1960s when the environmental protection movement had just emerged. Inspired by spacecraft, in 1966 American economist K. Boulding became acutely aware that to uncover the root of environmental questions it was necessary to enter the economic process.\(^{362}\) He advanced the famous theory of spaceship economics. He considered that the Earth looks like a spaceship flying in space and that the life it contains, including people, depends on the spending of the resources carried by it. If people continued to develop resources unreasonably and damage the environment, as in the past, he predicted that the Earth, like a spacecraft, would be destroyed. Therefore, the spaceship economy requires a new "circular economy" to replace the old single throughput economy. However, at that time most countries around the world were concentrating on the end control methods of how to govern to reduce the harm after the pollution had been produced. As a result, Boulding’s theory has not been given due attention.


Since the 1980s, people's awareness has led to the closing of some cycles. An example would be discharge water - purification of waste water - use waste water, as found in Singapore and London.\textsuperscript{363} However, regarding the fundamental question of whether the production of pollutants is reasonable, and whether antipollution measures should be charges to the source of the production, the majority of countries still lack the ideologically deep understanding of the problem and relevant legislation and policies. In 1990, British environmental economists D. Pearce and R. Turner in their book \textit{Economics of Natural Resources and the Environment} investigated the issue of material circulation thoroughly and from a resource management angle with greater emphasis on the theme of sustainable economic development. The concept of a circular economy\textsuperscript{364} was used for the first time in this book, which has since become a core text for undergraduate students of environmental economics, geography and all those who value the environment. Since the 1990s, and especially with the 1992 convening of the environment and development congress of the United Nations as well as the successful passing of Agenda 21, sustainable development has become recognized as a goal by various countries. More and more people have realized that the root of the serious environmental and contemporary resource problems lies in the characteristics of the linear economic model of high extraction, low use, high consumption and high emissions that has pervaded since industrialization.\textsuperscript{365} Since then, prevention at source and control of the entire process to avoid and contain contamination has gradually become mainstream policy in Western developed countries, such as the essential procedures in the US, Japan, German, French and the UK in the governing and protection of water body pollution and the water resources environment. Broadly this has been achieved through the comprehensive use of legal, administrative, and economic methods for integrated control and protection. In addition, these governments have promoted legislation, supervision and direct financial investment. This has led to the establishment of an investment system to stimulate the enthusiasm of government, private enterprise, and individual actions. All three partners are necessary for carrying out the environmental protection work of water effectively and sustainably.\textsuperscript{366} On the basis of maximizing resource utilization

\textsuperscript{364} Pearce, D. et al.(1990), \textit{Economics of Natural Resources and the Environment}, Baltimore: The Johns Hopkins University Press
\textsuperscript{366} Text proper in Chinese: 苏明: 部分发达国家水环境保护投融资的比较与借鉴, 财政部财政科学研究所研究报告, 第 62 期, (总第 1036 期), 2010 年 5 月 27 日. (Su, M, \textit{The comparison and reference in the investment and financing of protection in water}
and minimizing emissions, a set of systematic theories for a circular economy have been developed. For instance, this has led to the strategy of practicing clean technology, eco-industry, comprehensive utilization of resources, ecological design, and sustainable consumption patterns during the period 2006-2008 in China.367

The application of the theory of a circular economy in architecture is the closed-loop material cycle (CLMC). This type of construction can be described as building elements that can be recovered from buildings and infinitely recycled through natural or industrial processes.368 This means all designers will need guidance on the natural recovery of materials and design for deconstruction and recycling. A pilot CLMC assessment of selected building technologies has suggested CLMC construction is technically feasible.369 The developed CLMC criteria could be used to encourage the design of buildings associated with less waste and fewer environmental impacts. The more comprehensive nature of CLMC as an approach to waste minimization also broadens the options for waste reprocessing in buildings. The implications for mainstreaming CLMC at policy and practical levels will need to be considered for this approach to become the norm.370 The current situation in the Chinese building industry is very far from this ideal, as discussed below.

Over the past 30 years, from 1976 to 2006, China's economic growth was dependent on the consumption of massive resources and the emission of massive pollutants. For example in 2006 the Chinese GDP accounted for 5.5% of the world total, but China consumed 15%, 30% and 54% of the world consumption of coal, steel products and cement.371 Obviously if China's economic growth continues in this way, because China is congenitally deficient in energy and other natural resources compared with developed countries in the West, China's development prospects will give cause for

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369 Ibid.

370 Ibid.

371 Text proper in Chinese, 解放日报：诸大建教授在日本东京大学的演讲. 时间：2007年12月3日. Liberation Daily (December 3, 2007), Professor Dajián Zhu’s speech at the University of Tokyo, Japan
some anxiety. Therefore China's circular economy is not just aimed at dealing with solid waste disposal through a policy like the 3Rs (reduce, reuse, recycle) since China's economic development depends on using scarce resources, including water, land, energy, materials and dealing with the corresponding waste. To some extent, the development of sustainable systems for water, land, energy and consumption of other resources, and control of the associated pollution, has more pressing significance in China, again leading to the need for a circular economy.

China's total land area is third in the world in terms of size of country, but the average per capita land area is only 0.777 hectares which is 1/3 of the world's average land resources per capita. The Report on the State of Environment in China pointed out that in 2000 the total area of cultivated land in China was 128.2 million hectares, meaning the average per capita arable land area was 0.101 hectares which is less than half of the world's average per capita arable land. Because of the occupation of cultivated land for infrastructure construction, at present cultivated land across the country is decreasing progressively at an annual average rate of thousands of hectares.

With China's sustained and rapid economic and urban growth, the ecological environments of its cities are facing increased pressure. The Chinese version of the circular economy needs to be considered on a wider basis than those of countries like Germany and Japan with their focus on post-consumer waste. The latter mainly involves solid waste recycling and resource recovery, while China's circular economy requires applying the 3R principles to water, energy, land resources, raw materials and other fields, in order to maintain Chinese economic and social development but in a more sustainable way. Research aiming at raising the green competitive power of Shanghai and organized by the Shanghai Academy of Social Science once pointed out that the purpose of the circular economy is not just to

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374Text proper in Chinese, 中国科学院地理科学与资源研究所: 我国土地资源现状, 2006-03-07. Institute of Geographic Sciences and Natural Resources Research, CAS, China’s Current Status of Land Resources, Beijing: Institute of Geographic Sciences and Natural Resources Research, CAS

reduce the volume and weight of waste to be processed, so landfill sites and other waste disposal systems can be used for longer. Rather, it is to reduce fundamentally the depletion of natural resources and the environmental degradation caused by the linear economy. According to information from the Chinese Academy of Sciences and other research institutions, the natural resources restricting Chinese economic development, arranged in turn according to scarcity, are water, land, energy, and materials. Therefore, the development of a circular economy in China not only relates to saving scarce raw materials such as iron, manganese, aluminium, copper and other mineral resources, but also focuses on the development of water resources, land resources and energy resources, and efficient use of recycling. Taking into account the availability of natural resources and the ecological space in various Chinese areas, each place must aim to have its own characteristic circular economy. One serious consequence of this is the need to conserve land which means reusing it. In order to do this without constant rebuilding, and hence using materials, there needs to be a rethinking of the process of building procurement. One possible outcome will be the use of demountable buildings, designed for disassembly, together with producing flexible space in permanent buildings. Both approaches require an appropriate urban planning process which includes flexible land use, as discussed in Chapter 2 of this thesis.

9-4 Reusing Urban Space

9-4-1 Definitions of space

There are some differences in the understanding of open space in different countries. In 1906, the British “Open Space Act” defined it as “any land, whether enclosed or not, on which there are no buildings or of which not more than one-twentieth part is covered with buildings, and the whole or the remainder of which is laid out as a garden or is used for purposes of recreation, or lies waste and unoccupied.” The American “Housing Act” of 1961 stipulated that open space is any undeveloped or barely developed land in an urban area, which had the following values:

1) value for parks and recreation;

2) value for the protection of land and other natural resources;

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3) value for history or landscape.

As a state law of noticeable importance, effect and influence, the 1961 act provided $4.88 billion in loans and grants to cities, towns and rural areas for urban renewal, public housing, housing for the elderly, farm housing, college housing, community facilities, development of “open space” in cities, mass transportation, home improvement, housing for moderate-income families, and the FHA home mortgage insurance program.\(^{379}\) Japanese scholars\(^{380}\) believe that open space consists of two main parts, public green and private green spaces. Alexander thought any space that can comfort people, which has a natural character, or from which a wider space can be seen, can be called open space.\(^{381}\) Some opinions have believed that open space means vacant land, water areas, or land totally not covered by artificial structures.\(^{382}\) Chinese scholars have quite different definitions of open space. Some have argued that it means urban public external space, including natural scenery, squares, roads, public green land and recreation space.\(^{383}\)

It is clear that these definitions have a significant common ground, that is, open space is the space enclosed by physical entities, and in which the floor of urban space is ground. The meaning of modern urban open space has been greatly expanded, to include urban space occupied or formatted by entities such as large municipal facilities like bridges, viaducts, and urban light rail. All these belong in the scope of modern urban open space when it comes to province and city planning.\(^{384}\)

In order to facilitate this study, urban open space can be divided into two types, city artificial open space and city natural open space, according to the degree of artificialization. Generally speaking, most city artificial open space is within the city, which means a higher artificial degree and a lower naturalized degree; on the other hand, most city natural open space is located in the urban fringe or in


\(^{380}\) 高原荣重著，杨增志等译：《城市绿地规划》，中国建筑工业出版社，北京，1983

\(^{381}\) Alexander Garvin, et al. (1997), Urban Parks and Open Space, Urban Land Institute (Corporate Author)


the suburbs, which means a higher naturalized degree and a lower artificial degree. These definitions are important when it comes to the placing of temporary structures. The former type of open space—more artificial in character and within the city—is better suited to such use. As Myers summarised:

*As the counterpart of development, urban open space is a natural and cultural resource, synonymous with neither 'unused land' nor 'park and recreation areas.' Open space is land and/or water area with its surface open to the sky, consciously acquired or publicly regulated to serve conservation and urban shaping functions in addition to providing recreational opportunities.*

9-4-2 Urban public space and its extended sense

The more popular urbanization becomes, the more the concept of urban public space is being adapted. Urban public space can be simply defined as urban public common use space, namely, the part of urban space which belongs to the public or public value domain, making it a kind of public goods. However, up to now there is still not yet a fully unified understanding about its specific concept. Widely used in Chinese planning institutions, *City Planning Principles* (3rd edition) have adopted a definition in which the narrow concept of urban public space is the outdoor space offered for urban residents to use as part of their daily, social life, including streets, squares, residential outdoor venues, public parks, and sports grounds. According to the life demands of the residents, they can undertake transport, commerce and trade shows, exhibitions, sports competitions, sports and fitness activities, rest, sight-seeing, holiday gathering and social communication. Public space is also divided into open space, which remains the street, square, parking, residential green land, street green land and public park; and special space, which includes playgrounds and special facilities like zoos and botanical gardens. The broad concept of urban public space can be extended to the land used for communal facilities, for example, urban centres, commercial areas, and urban green land. In these definitions, materially, public space is outdoor space. In addition, the definition of open space is divided by the freedom for undertaking different activities of people using it, that is, open use space and special use space.

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The meanings of urban public space and urban open space are close but there are still some differences. Some Chinese scholars have argued that urban public space is the urban open space dominated by artificial factors from the viewpoint of human participation. Some believe that urban public space is urban space included in the public value domain, which is mainly city artificial open space or the open space in a city dominated by artificial factors.

Differing from some Chinese scholars who put more stress on the physical, touchable and property ownership side regarding the meaning of urban public space, most European and American urban scholars and practitioners give more of an emphasis to the interactions between human beings in the urban context through the medium of urban space. For examples, the top winner of the 2010 European Prize for Urban Public Space, the Open Air Library (Fig.9-1) in Magdeburg, Germany, was constructed with prefabricated pieces from a demolished building by the residents of a socially depressed neighbourhood after a participative process. Another joint winner, the Den Norske Opera and Ballett (Fig. 9-2) in Oslo, Norway, also offers community interaction. Its roof gently emerges from the waters of the port of Bjørvika to offer people who walk on it splendid views over the city and the fjord. Both built cases illustrate the essential and distinguishing attribute of urban public space which is that it is closely related and connected with people in a certain environment.

Fig. 9-1 (left), Open Air Library in Magdeburg, Germany. Fig. 9-2 (right), Den Norske Opera and Ballett in Oslo, Norway (Resource: Centre de Cultura Contemporània de Barcelona - www.cccb.org).


388 The European Prize for Urban Public Space is a biennial competition organized by six European institutions with the aim of recognizing and encouraging recovery projects and defense of public space in today’s European cities.
From the sensible and realistic point of view, urban public space is a social space such as a town square, side walk, civic centre, or public library. These places are open and accessible to all, regardless of gender, race, ethnicity, age or socio-economic level. Good public spaces, at the time of their creation, diversify without losing identity, improve the local economy, help the environment, and provide settings for cultural and social activities. “If public space can be considered as an active urban void and allowed to construct its identity by their users, it would be creating an opportunity for the sustainability of these spaces in the future.”

The end product of place making in terms of inclusive public spaces is essential to ensuring liveable, sustainable cities of the future.

### 9-4-3 Enjoyment as the main function of recreation space

As one type of major urban public space, recreation space widely refers to the places where people have entertainment, fun, and social contact. In fact the diversities of its planning, design and pattern have also become “essentially a quality-of-life issue.” In Europe and America, general recreation spaces include those with a building focus (hotels (including motels), restaurants, theatres, concert halls, cultural centres, museums, pool rooms, bowling alleys, swimming pools), those with buildings associated without outdoor recreation space (stadia, tennis clubs, theme parks) and those where the outside space dominates (equestrian fields, boat clubs, fishing parks, shooting moors, ski resorts, playgrounds, holiday farms, holiday ranches, camping sites, picnic areas and natural scenery).

Moving away from the traditional concept of space for physical activity, modern recreation space is concerned more about cultural or spiritual atmosphere, cultural experience, cultural communication, and cultural appreciation between people. Concerns are now more about the harmony between human beings and nature and development to reflect this. The City of London, with the 2012 Olympics as a backdrop, is using the need for the creation of recreation space to attempt to become the world’s “greenest” city by 2012. Modern recreation space is part of the creation of human culture, and also the carrier for human cultural heritage, and has been in places a synthetic cultural and

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ecological environment for people to touch civilization, understand culture, and appreciate the relationship between people and the environment. The recently opened John Hope Gateway (Fig.9-3) at the Royal Botanic Garden Edinburgh\textsuperscript{393} can be seen as one of the best modern examples to interpret the function of public space. Its aim is to meet people’s psychological needs and spiritual needs, and shape and upgrade the cultural and spiritual characters of people.

In order to understand recreation space more precisely and in-depth, it is necessary to expand its scope, that is, recreation space is the space system which consists of physical space and recreation action space, acting as a recreational landscape.\textsuperscript{394} Recreation thus includes all aspects of the natural environment as well as the traditional active play components. Recreational physical space is environmental space composed of tangible recreation facilities such space for activities and related building facilities, to create a variety of tangible material forms. Physical space is the carrier of action, where recreational activities are carried out in appropriate recreation space. Recreation behaviour space is an invisible but objective existing form, which is the projection left on the surface of a space through recreation activities, and these will also include the transport to reach the space. Behaviour space has some regularity; it may be the same as the physical space, but may also be inconsistent with it. When the behaviour space is larger than the physical space, there will be the situation of recreational demand exceeding supply. At this point, those engaging in recreational activities can exert pressure on and even damage recreational facilities and the environment, a process which is known as over recreation. Otherwise, when behaviour space is smaller than the physical space, this will mean the recreational facilities are idle and there is waste of recreational space, expressed as lack of effective demand for recreation.\textsuperscript{395} Both needs require keeping the greatest degree of unity, so that they can bring out the best in each other. But, if the

\begin{itemize}
\item [393]http://www.edinburgharchitecture.co.uk/royal_botanic_gardens.htm
\end{itemize}
physical space can be prepared in more flexible forms it could play an important adjustment role in such interaction.

Focussing on physical properties, urban recreation space just refers to urban space with a recreational function and certain recreational facilities. It is a part of urban space, especially urban open space, and in some instances is the city's main venue for people to experience spirit and culture. It includes urban public space (urban artificial open space) with recreational functions and natural urban open space. Urban recreation space shows more concern for the recreational functions of the space, and has critical differences in division of form and form definition when compared with urban public space and urban natural open space. Some urban public space is one kind of recreation space because it has recreational functions and is even loaded with recreational activities, such as a park or city square (Fig.9-4 to 9-6); while other public space, like roads, although sometimes used for recreational functions like cycle races, are often more characterized as traffic space rather than open space.

Therefore, urban recreation space can be given the following boundaries: urban recreation space refers to urban open space in urban or suburban conditions where recreational activities are carried out. It is a complex system with a certain arrangement of structure, function and dynamics, with reciprocity and relationships between its various elements. Urban recreation space contains two main parts. The hardware mainly consists of recreational products, recreational facilities, visual identity, location characteristics and ecological environment elements. The software is recognised because the space has identification, behaviour recognition, is formed under policies and regulations, and there is management security and technology protection. Usually designers and planners only focus on the hardware side but creating a good urban recreation space environment is bound to depend on the
software side, as the integration of the two parts together affects the quality of recreation space. A
good urban recreation space should contain system, hierarchy, openness, sense of place, ambiguity,
amenity, ecology, and cultural qualities.

9-4-4 Public spaces make a better city – the example of Barcelona

In 1975 Barcelona was a dilapidated and devastated city. At that time, its government carried out an
urban planning exercise which aimed to improve the urban public space and living environment
gradually instead of changing the city through implementation of a comprehensive master plan. This
approach became famous as in 1980 the urban designer of Barcelona's city council launched a plan to
rebuild the city. The rebuilding procedure was started by giving attention to small public spaces,
such as turning abandoned land and parking lots into community parks. The design method was
simple; people and the buildings around them were the main focus of any proposed changes. Although
the expenditure on the changes was very little, the rejuvenated abandoned land quickly became
intimate spaces for the local residents, making Barcelona become a habitable city. This was followed
by making abandoned land north of the railway station into an amusement park, recovering the space
occupied by cars and making this into small squares, and narrowing a vehicle lane which was too
broad to form a continuous landscape around a pedestrian path. The goal in this was to secure some
good public activity venues for Barcelona. Since then, public space has become the most important
thing in the city, and taking care of the quality of public space a most important public policy. This
kind of care should not just be an expedient measure, but a permanent policy leading to continual
action. The whole approach showed that improvement of small public spaces could lead to a series of
chain reactions relating to peripheral functions, and embracing environmental, economic and social
activities.

More than one hundred and forty urban spaces were designed over the seven-year period
(1981-1988), which clearly contributed to an intense renovation of Barcelona’s urban landscape,
as well as to the revitalization of its urban identity. Those urban projects, almost all of which
were at a small scale, had a transforming effect beyond their immediate environment, in that
they formed part of a broader urban project. This model of urban transformation, in which
large-scale changes and substantial objectives are obtained on the basis of numerous small and
individual strategically situated interventions, has been labelled ‘Urban Acupuncture’. More

than 140 urban public spaces have been designed and built during these seven years, and not only that Barcelona changed its urban landscape, but it reinforced its identity and became an international laboratory for urban design. \(^{397}\)

All of these actions, to some extent, revived the city and ushered in new development opportunities. In 1992, Barcelona successfully won the bid for the Olympic Games. The chosen venue for the games was the abandoned site of the 1929 Expo, which is near the waterfront area.

*The use of this area for the Olympics brought about a general refurbishment of the park and the consolidation of its function as a significant part of the city....The Olympics provided a justification for the redevelopment of the area. The preparation for the Games also led to the renovation of the city's cultural infrastructure, including the National Museum of Art of Catalonia, Municipal Auditorium, National Theatre of Catalonia, Centre of Contemporary Culture, Museum of Contemporary Art and a new Botanical Garden.* \(^{398}\)

With the coming of the Olympic Games the venues have become a fascinating residential community and a popular tourist destination. In this way the city of Barcelona has been reborn. Everywhere is now brimming with vitality and vigor. Barcelona has thus won its reputation as one of the most fashionable and appealing cities in the world.

The example of Barcelona suggests that improving the quality of urban public space is an important means for guiding the healthy development of the city; it may well be more important than introducing investment projects. Small squares, small gardens, small parks and user-friendly streets are the key to success and are more effective than what could be achieved with large investment. The improvement of public space will induce a corresponding change to private space. It is also clear that this process takes time. It suggests sustainable urban development always requires a course of gradual change and that qualitative change is more important than quantitative change. If this idea is applied to events like Expos, it suggests that rather than large scale development of a single site, which as has been argued in this thesis often leads to a waste of land and the resources in the Expo buildings, it


would be better to think of an Expo as a series of small interventions on small areas of available land throughout the city. These interventions would be temporary, as after the event the land could be returned to its former community use. The communities thus give up their amenity land for the period of the Expo, and benefit from the money put into the local economy, but afterwards the land is effectively returned to them.

9-4-5 A new conception: urban usable space

There is a need to seek a term that suggests a closer relationship or interactive connection between urban open space and urban development. As part of a subdivision model of urban structure, “usable space” was first mentioned in 1977 in the book Urban Transport Economics. At that period, these spaces included public parks and open spaces which fulfilled functions similar to public streets, in being open for public use free of charge. Also included were public green spaces, recreation areas, playgrounds, and some athletics fields, and paddling pools. Usually these areas and facilities could be entered and used unchecked, although there were often rules and regulations for use on display. However, as urbanization continues to proliferate problems have emerged with the care and control of these spaces. Nissen has discussed this problem in depth and his important conclusions are reproduced in full.

With respect to the city administration’s task of maintaining its public gardens mainly four trends can be observed: 1) local authorities maintain the responsibility for care and (re)organization of parks and public plazas. The effort to increase their attractiveness to middle-class citizens can be taken as one of the main goals of the local commitment to the city’s parks and open spaces. In order to reach this aim, public area uses are de facto redefined towards middle-class interests. 2) Private companies, activity groups or residents take over the maintenance tasks of public parks. 3) The complete park, plaza or other open space enters a privatisation process. 4) Public parks are neglected or even closed, and private spaces taking over their functions, but with limited access. … Each of these trends can include reconstruction and reshaping that works especially on the symbolic level. These symbols contribute to the

definition of public spaces as a public usable space or as a space with reduced public access and usability.\textsuperscript{400}

His observations indicate that at a time of urban sprawl, cities are reducing their public parks and the clear distinction between public and private space is becoming blurred. Instead, urban spaces of hybrid character are emerging.

Synthesizing the above definitions based on the sustainable development concept, a definition of urban usable space emerges as an exchange centre for information, material, and energy between people and between people and nature. The hybrid nature of the space, in being neither entirely public nor entirely private gives it more flexibility in use. Such a space could be used by a local community in a way that makes it appear ‘private’ to that community but, as suggested above, at other times it could be used for a temporary event like a trade show by a private company, but opening it to the paying public. This is the essence of public usable space and it is these spaces that will belong to the Expos of the future. Such urban spaces would also help to alleviate some of the urban problems that come with “over building” as discussed below.

9-5 Public Usable Space and the Urban Heat Island Effect (UHI)

9-5-1 Urbanization pressure

As early as 2005 the UN sounded a warning about urbanization trends. “Until now humankind has lived and worked primarily in rural areas. But the world is about to leave its rural past behind: By 2008, for the first time, more than half of the globe’s population, 3.3 billion people will be living in towns and cities.”\textsuperscript{401}

This prediction has unfortunately come true. As the United Nations Population Fund has pointed out, the number and proportion of urban dwellers will continue to rise quickly, “the world’s urban population is expected to increase from 3.2 billion in 2005 to 4.9 billion in 2030.”\textsuperscript{402} In comparison,

\textsuperscript{400}Nissen, S., Urban Transformation From Public and Private Space to Spaces of Hybrid Character, Czech Sociological Review, 2008, Vol.44, No.6: 1129-1149

\textsuperscript{401}United Nations(2006), World Urbanization Prospects: The 2005 Revision, New York: Population Division, Department of Economic and Social Affairs, United Nations

\textsuperscript{402}Executive Summary, www.un.org/esa/population/.../2005WUPHighlights_Exec_Sum.pdf
the world’s rural population is expected to decrease by some 28 million between 2005 and 2030. At the global level, all future population growth will thus be in towns and cities. Most of this growth will be in developing countries. The urban population of Africa and Asia is expected to double between 2000 and 2030. It will also continue to expand, but more slowly, in Latin America and the Caribbean. Meanwhile, the urban population of the developed world is expected to grow relatively little: from 870 million to 1.01 billion. This vast urban expansion in developing countries has global implications. Cities are already the locus of nearly all major economic, social, demographic and environmental transformations. What happens in the cities of the less developed world in coming years will undoubtedly shape the prospects for global economic growth, poverty alleviation, population stabilization, environmental sustainability and, with these, the exercise of human rights.\footnote{The United Nations Population Fund (UNFPA), \textit{State of World Population 2007: Unleashing the Potential of Urban Growth}, online report: United Nations Population Fund}

This congregation into cities has far-reaching implications for the future of urbanization. On one side, the city is the symbol of human civilization and the centre for people’s economic, political and social lives. The degree of urbanization is an important symbol for measuring a nation’s or region’s economic, social, cultural, scientific and technological level, as well as the level of national and regional social organization and management. Urbanization is inevitable in human progress because the city is symbolic of structural change in human society. Cities are synonymous with the goal of modernisation. However, like a lot of progress, the process of urbanization is also associated with some discord, such as causing environmental degradation and shortage of natural resources. One problem that directly affects those living in cities and that relates to public usable space in the urban heat island (UHI). This product of urbanization is closely related with a growing urban population, the resulting buildings and their layout.

\section*{9-5-2 Key factors of UHI}

Urban areas are associated with highly condensed land uses for people, commerce, industry and transportation. Because of the discharges from energy used for heating and cooling in large quantities the temperature in a metropolitan area is significantly higher than that in its surrounding suburban districts. This phenomenon is called the urban heat island effect (UHI).
can be found in *The climate of London*,\(^{404}\) in which the author, Howard described two things. The first was that the temperature in central London was higher than that outside London (the monthly average was 0.5°C -1.2°C higher), and the second was that temperature differences between urban and rural areas at night were bigger than during the day. Along with increased densification of cities around the world and a continually growing urban population, the UHI has become increasingly prominent. China has observed some of the largest temperature differences between urban and rural areas (a measure of the intensity of UHI); one was on November 13, 1979 20:00 in Shanghai of 6.8°C; and the other on February 22, 1966 in the morning in Beijing of 9.0°C.

Taking Taipei in northern Taiwan as another example, the city is located in the subtropical zone with year-round rain and no obvious dry seasons. Its estimated population was 3.5 million in 2000\(^{405}\) and it had a population density of 9,674 people per sq. km by the end of 2007\(^{406}\) making it the largest city in terms of overall population and ranking second in Taiwan, with only 226 persons less than the population density of Kaohsiung City. Taipei has some small areas that are crowded with people. People, trade, and industry have obviously gathered together in these urban areas (Fig.9-7).

Since the latter half of the 20th century, Taiwan has experienced significant changes in its social and cultural system due to economic growth and political reform. “Over the last half century, real GNP and real GNP per capita have grown from approximately US$6 billion to over US$300 billion and from slightly more than US$700 to almost US$13,000 (2000 prices), achieving rates of growth of more than 8% and 6% per annum respectively.”\(^{407}\) This rapidly growing economy expedited the

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\(^{404}\)Howard, L., *The climate of London, deduced from Meteorological observations, made at different places in the neighbourhood of the metropolis*, 2 vol., London, 1818-20


\(^{406}\)Source: Department of Civil Affairs, Taipei City Government. Statistics, Table 2 : Statistics on Population for Taipei City, Date:2009/9/3

development of fast urbanization in Taiwan. Both the world's tallest building from 2004 to 2010 (Taipei 101) and, at a total cost US$15 billion,\textsuperscript{408} Taiwan’s High Speed Rail System (THSR), were products of that unusual time.

Taipei’s urban areas have large quantities of concrete pavement, numerous skyscrapers and three-dimensional public transportation systems. This hard landscape will absorb large amounts of solar radiation, gradually releasing it as heat at night. However, this heat will not be sent out completely until the next morning and then follows a full day of sun. This, coupled with continued emissions from air conditioning systems has finally made the summer average temperature rise of the urban heat island effect increase year after year. So some researchers have claimed that Taiwan, and especially the city of Taipei, is experiencing a significant UHI effect due to its high population density and the uniqueness of its geographic structure.\textsuperscript{409}

The frequency and intensity of UHI are intimately related with urban zoning which can be divided into commercial, industrial, residential and forest landscape. Through a study using fixed point measurements, research based on the city of Guangzhou\textsuperscript{410} showed that the influences of commercial landscape and forest landscape on the urban heat island effect were significant. The effect of commercial landscape on UHI increased it, while the effect of forest landscape on it tended to be negative.

In the same subtropics zone, a Hong Kong study published in 2008 and carried out by the Hong Kong Observatory\textsuperscript{411} showed that the rising trends of air temperature in Hong Kong are influenced by both global warming due to the enhanced greenhouse effect and the high density urban development in Hong Kong. Apart from temperature, the study reported that urbanization also brings about obvious

\textsuperscript{408} The China Post, \textit{HSR system sets several world records}, 2007-01-05
\textsuperscript{409} Lin, C. et al., \textit{Urban Heat Island Effect and its Impact on Boundary Layer Development and precipitation over Northern Taiwan}, American Geophysical Union, Fall Meeting 2007 and the Seventh International Conference on Urban Climate, June 2009, Japan
\textsuperscript{411} Wu, M.C., et al. \textit{A study on the difference between urban and rural climate in Hong Kong}, 22nd Session of Guangdong, Hong Kong, Marco Meteorology Science and Technology Seminar, January 2008, Zhongshan, China
differences between the urban and rural areas in respect of other meteorological elements such as wind speed and relative humidity.

### 9-5-3 UHI can be harmful to humans

“Urban heat islands can be impacted as the daytime UHI often accelerates the formation of harmful smog, as ozone precursors such as nitrous oxides (NOx) ...” Extreme heat events (EHE), which can be defined as periods of abnormally hot and often humid weather, are dangerous to some and can result in increased rates of heat-related mortality and morbidity. The Centres for Disease Control and Prevention estimates that in the United States from 1979 to 2003, excessive heat exposure contributed to more than 8,000 premature deaths. This figure exceeds the number of mortalities resulting from hurricanes, lightning, tornados, floods, and earthquakes combined.

By increasing day-time temperatures and reducing night-time cooling, heat islands can exacerbate the impact of EHEs. Populations who are vulnerable to heat, such as children, seniors, and people with chronic illness, are at particular risk of general discomfort, respiratory difficulties, heat cramps, exhaustion, heat stroke, and heat-related mortality. UHI also affects indoor thermal characteristics (such as air temperature, humidity and air movement), especially in buildings where air conditioners and mechanical ventilation systems are not available.

### 9-5-4 The UHI in Shanghai

It is generally believed that physio-climatic and geographical conditions are the external contributors to the urban heat island effect (UHIE), while urbanization is its internal contributor. Thus there are three causes that contribute to the UHIE. First is the difference in earth surface properties between urban and rural areas. Compared with the suburbs, the city is characterized by less reflectivity, more heat absorption, less heat loss by evaporation, quicker heat conduction, and slower radiation heat dissipation. Second, the quantity of heat produced by people in the city is much larger than that in the suburbs. Third, the air in the city contains more pollutants and more aerosol particles, which to some extent preserve heat.

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412 Golden, JS, The built environment induced urban heat island effect in rapidly urbanizing arid regions–a sustainable urban engineering complexity, *Journal of Integrative Environmental Sciences*, 2004 - Taylor & Francis

In fact, the main contributor to the UHIE is the city, especially the city centre, in which there are high plot ratios, dense populations and buildings which give rise to urban heat. As an example, since the 1980s, the maximum air temperature in the centre of Shanghai has been far higher than that in the suburbs, and the number of days of highest temperature has also been much greater. As a result the UHIE has become more obvious. Between 2003 and 2005, the density of both people and buildings reached unprecedented increments in speed and height. According to a quantitative analysis of the surface temperature of the ground in Shanghai city and its ability to reflect variations indirectly in the UHIE, the average highest surface temperature in Shanghai city is 13.9°C in winter, 32.5°C in spring, 45.7°C in summer and 29°C in autumn. The city centre in winter is characterized by a weak cold island centre, while in the other three seasons it forms a heat island centre, of which the heat island in summer reaches a maximum. The surface temperature in the winter weak cold island centre is 2.6°C lower than that in the suburbs, while in spring, summer, and autumn, the average temperatures are respectively 5.7°C, 10.4°C and 4.2°C higher than in the suburbs. Huangpu District, Luwan District and Jing’an District, located in the centre of Shanghai, are the highest intensive UHIE regions, and the junction of these three districts is always “the super high-temperature zone” and is of concern to the meteorological department.414

9-6 Tactics for Reducing Urban Sprawl and Carbon Emissions

Since World War II urban sprawl has become a widespread phenomenon in western cities. However, in practical research work it is very difficult to define what is meant by urban sprawl clearly. Even so, it is necessary to define this phenomenon for this particular investigation.

Downs considered that urban sprawl is a specific form of suburbanization that involves extremely low-density settlement at the far edges of the settled area, spreading out far into previously undeveloped land.415 The urban economist Mills also thinks that urban sprawl means excessive

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suburbanization.\textsuperscript{416} Penda\textsuperscript{417} takes this further, advocating that suburban sprawl is a phenomenon of low density urbanization. Urban sprawl often happens quickly, as opposed to gradually. Another key characteristic is its low-density land use, where the amount of land consumed per capita is much higher than in more densely populated city areas. Wide streets, large lawns, and landscaping are typical in this pattern. Subdivisions are perhaps the primary example of the less efficient use of space that characterizes sprawl. These layouts often only have a few places to enter and exit, causing main roads to have more traffic at these points. Thus the search for space through these low density developments often creates problems, like local traffic congestion, that impinge on daily life.

Many traditional European cities, typically many small and mid-sized cities as are found in Holland and Belgium, have been established in a compact and efficient way. In Holland thousands of hectares have been reclaimed from the sea and turned over to arable land and pasture, so perhaps the fact the Dutch have had to work hard to gain this arable land means they are not keen to see it lost to urbanisation. However, many people, especially in the United States, prefer to have suburban development in an outward instead of an upward manner. Developments such as shopping malls, fast food chains, strip malls, and housing subdivisions are especially typical of the urban sprawl resulting from this approach. This phenomenon has occurred more around metropolitan areas and typical examples can be found in the urban agglomerations around the city of New York. The same situation can be found in the rapid urbanization of China, such as the urban agglomeration of the Yangtze River Delta with Shanghai as its centre, the Zhujiang Delta with Guangzhou as its centre and the Bohai Sea Rim Area with Beijing and Tianjin as the centres.

To avoid urban sprawl it is necessary to build at higher densities but to do this in such a way that the problems associated with high density living, such as the UHIE, are avoided. This means that urban public space is not just a desirable thing to have but a vital component of modern high density cities in order to make them acceptable places to live and avoid issues like the UHIE. However, as suggested


\textsuperscript{417}Penda Hair is the author of the Rockefeller Foundation's report on innovative civil rights strategies, Louder Than Words: Lawyers, Communities, and the Struggle for Justice (2001) and former Washington, DC office director of the NAACP Legal Defence and Educational Fund, Inc.
before, this urban public space can then be made available for temporary uses that involve the erection of demountable, temporary buildings.

9-7 The Ecological City

Although so far there is no real consensus of what is meant by the term eco-city, from the perspective of modern ecology, an ecological city should be based on the principles of ecology. Fundamentally, it has to be a sustainable city within a healthy ecosystem. It does not just mean a city with many trees, or a city with a low carbon footprint. The eco-city has to be a place where people live within their local resources and within the fair share of resources available to them. Thus arable land for food and land for growing energy have to be readily available to meet the needs of people living at higher densities. This complex topic is beyond the scope of this investigation. However, flexible land use and demountable buildings may well form some of the elements of a future eco-city. The ratio of green space or greening rate may form the main index of a liveable city, but this alone will not make an eco-city. The beauty of a modern city, not only lies in how many tall buildings, wide roads and large squares are there, but more importantly in its naturalness, careful use of resources and ecological beauty.

9-8 Land Saving

According to statistics from the Department of Agriculture in Shanghai, there was a total of 4204 square kilometers of agricultural land in the city in 1981. This was reduced to a total of 3280.8 square kilometers of agricultural land in 1996. Over 15 years, the city lost 923.2 square kilometers of agricultural land, the average annual decrease being 61.55 square kilometers. The area in Shanghai called Pudong is an example of how this came about.

Since 1996 central government gave priority to developing Pudong. As a result, the municipal government, as part of opening up Pudong, embarked on a new round of ten infrastructure projects. These included the Pudong International Airport, the second phase of the Waigaoqiao port area, the Pudong International Information Port and the Metro Line 2 works. Because of these large projects, Pudong changed from a suburban countryside area to become the symbol of new urban Shanghai.

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On December 8, 1999 China formally applied to bid for the World Expo 2010 and on December 3, 2002, Shanghai successfully won the bid. As a result Shanghai began another round of large-scale infrastructure construction, thus, the demand for land reached a peak. During the period of 1996 to 2004, in Shanghai 385.1 square kilometres of arable land were lost to construction; overall 85.21% of the total agricultural land was turned into construction land. So, agricultural land has been largely appropriated by urban and suburban construction because of its relatively low economic value. It can be said that construction and hence urbanization has been the main factor in reducing Shanghai’s immediately available arable and agricultural land.

A study supported by the National Natural Science Foundation of China indicated that between 1997-2005 when cities expanded by occupying arable land, if independent industry and mining is counted in, the top five provincial territories which occupy most arable land in China are Shanghai, Henan, Zhejiang, Jiangsu and Shandong. In fact, the first four of the five have fairly robust economic strength and domestic competitiveness in the history of modern China. According to the 2005 list of GDP per capita for various Chinese provinces (exchange rate 1USdollar was 8.1917 Yuan at that time), Shanghai, Zhejiang, Jiangsu, Shandong and Henan were respectively 51,530 ($6,291), 27,703 ($3,382), 24,560 ($2,998), 20,096 ($2,453) and 11,346 ($1,385), and listed as 1st, 4th, 5th, 7th and 17th nationwide. The only exception in the study is Henan, which is considered a less developed region and an agricultural province, traditionally with a high population. The reason the province was listed as 17th for average GDP and ranked 2nd in the list of occupying most arable land in China was the appearance of small independent mining developments and their associated industries which were blossoming across the province in that period. Since 2003, the Henan coal industry achieved an output
value that makes up 10% of provincial GDP, and this industry is the mainstay of the continuous economic growth of Henan, which has been in double-digits for many years.\textsuperscript{423}

As a quasi-world class city, Shanghai’s urban population and its industries are over-concentrated; the carrying capacity of the land is extremely high. According to an official document issued by the Shanghai Municipal Planning and Land Resources Administrative Bureau,\textsuperscript{424} Shanghai’s land area based on the 10 old city districts is 278.81 square kilometres which only occupies 3.51% of the whole city land area, but actually has concentrated within it 52% of the whole city’s population. By 1996 the population density reached 22,634 people per square kilometre. Huangpu District contained 58,964 people, and Nanshi District 60,049 people.\textsuperscript{425} Regarding land-use structure in the central city, the land for trade and service industries accounted for 3.4% which was lower than that found in developed countries (13%). The land for industry and warehousing accounted for 26.73% which was higher than in developed countries (13%). The average urban road area per capita was only 2 square metres which was 1/10 of London’s; 1/4 of that of Paris; and 1/3 of that of Tokyo, Moscow and Beijing.\textsuperscript{426} The residential land, public buildings and urban green spaces are also lower resulting in the obvious phenomena of traffic congestion and environmental pollution.

Being the second regional metropolis of the Yangtze River Delta and only inferior to Shanghai, the capital of Zhejiang Province, Hangzhou, in 1990-2000 reduced the total sown land areas by 411.8 square kilometres, which was mainly a reduction in grain sown area by 270.60 square kilometres.\textsuperscript{427}

From this phenomenon and analyses it is not difficult to see that growth in GDP is an important factor in urbanization and has a great impact, especially for a densely populated country like China. If China

\textsuperscript{425} Ibid.
\textsuperscript{426} Ibid.
is to move towards sustainability it is obvious that the present path of economic development and urbanisation cannot be maintained. As one small part of what is required, this thesis argues that the insertion of flexible public usable space into the cities is vital, and that this can be paired with flexible demountable buildings.
CHAPTER 10  KOP STRUCTURE AS A GREENER SOLUTION FOR EVENTS BUILDINGS

This research has suggested that the BYHT could be viewed as a new direction for sustainable events buildings, because it is reusable and hence avoids unnecessary waste of materials. Being in essence a KOP system, the need is for a contemporary concept of adaptability directly derived from such precedents but allowing that “reconfigurability is an important aspect of changeability.”

One unique advantage of kit-of-parts (KOP) structures is that, at the end of their useable lives, they can be dismantled into many pieces or single elements. While it is well known that single elements can be recycled, it also is possible that almost all materials can be recovered from the demolition site and sent to another site for reuse on a new project. However, without pre-planning this can be a haphazard process. Being flexible and changeable to suit different sites, the KOP structure offers opportunities for reclaiming and reusing single elements, parts and components. In this way a KOP structure is able to be changed over its life cycle to adapt to the changing needs of the end users. This can also provide a strong environmental option not available with many other buildings designed and constructed using a conventional approach.

The question is whether this approach can serve for sustainable mega-event buildings, especially in terms of the relationship between events building and the city environment. This chapter will further explore the attributes of KOP from diverse aspects in answer to this question.

10-1  Mega-events, Buildings and the Environment

A mega-event not only shows the achievements of aspects of society like technology, manufacturing, culture, and sports, but in different styles often becomes a part of city festivals. There is no lack of design creation when it comes to making events buildings with the goal of their becoming a city landmark. However what happens after the events for most of these sites suggests their design is out of touch with the development of the host city, as they usually exist without connection to overall city development. They are removed at the end of their time and become construction waste, failing to be transferred to a permanent use as part of the city.

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This phenomenon continued until the 1980s when the idea of sustainable development was first formally put forward by the Brundtland Commission. In 2000 William McDonough and Michael Braungart applied these ideas to the Hanover Expo in Germany, along with a general understanding of environmental issues.\textsuperscript{429} However, this was not the first time the environment had formed some part of an expo theme. For more than two centuries after the Industrial Revolution, human beings with limited thinking had taken sunlight, air, water and land as being inexhaustible, so scientific invention and technological innovation had been the only themes for world expos until the Osaka Expo in 1970. Expos turned towards environmental issues because people in developed countries had found that environmental disasters brought about by industrialization had grown to threaten the safety of human life. As an example of this, Japan’s GNP had grown until Japan was the second largest economy in the world, when in 1968 its national production surpassed that of the German Federal Republic.\textsuperscript{430} However, in the same year social evils from deterioration of the natural environment suddenly emerged: first, was the sudden inexplicable death of hundreds and thousands of chickens, followed by that of 1684 patients with acute poisoning. Meanwhile, people in places like Minamata Bay and Kumanoto Prefecture suffered numbness, inarticulacy, limb tremor deformation, and mental disorders.\textsuperscript{431} According to statistics, half of the world’s eight great natural events in the 20th century happened in Japan\textsuperscript{432}, and this series of environmental crises caused the Japanese government to give greater attention to the natural environment. As a result, “Human progress and harmony” was the theme of the Osaka World Expo, clearly putting the relationship between man and nature as an issue to be investigated.

Since the Osaka World Expo, people have begun to transfer their visions of the future from the blind pursuit of scientific and technological progress to the relationship between technology and nature. As part of this movement, the German Hanover World Expo is commonly recognized as a milestone in the concept of sustainable development. The successful Lillehammer Winter games of 1994 in Norway were another important milestone as the aim was to create a green sports event, with the

\textsuperscript{429} In 1991 William McDonough and Michael Braungart co-authored \textit{The Hannover Principles: a set of design guidelines for the Hanover Expo in 2000} that were issued at the 1992 World Urban Forum of the Earth Summit.

\textsuperscript{430} Koichi Hamada (1996), \textit{Japan 1968: a reflection point during the era of the economic miracle}, Center Discussion Paper No. 764, \textit{Economic Growth Center, Yale University}


\textsuperscript{432} Ibid.
London 2012 Olympics as a yet another milestone in environmentally responsible sports venues, this time linked to sustainable urban development.

10-2 Analysis Criteria for a Sustainable Mega-event Building

The sustainable mega-event building is a fairly broad concept, but the analysis criteria for it entail the following:

- Is there comprehensive consideration given to the sustainable utilization of the buildings from the start of their design? Under the guidance of systems theory and from the standpoint of the overall lifecycle of the buildings, proper comprehensive consideration should be given to the utilization of resources and energy at different stages of the building: such as material use, construction, use and maintenance, and demolition, so as to reduce the waste of materials and design environment-friendly buildings.

- Is the building environmentally friendly? This means two things: firstly constructing the building so it is safe for the surrounding environment and will not significantly interfere with any wild life and its patterns of daily life, and that it will not negatively affect the natural environment nearby; secondly, the building is constructed from environmentally friendly materials that are available locally and the construction process is well designed to reduce the unnecessary pollution and negative effects on the environment.

- Are all resources used efficiently? This means using water saving faucets and plumbing elements, energy efficient lighting units and passive solar design. It also involves the use of building materials aimed to attain a highly energy efficient building envelope with well insulated walls, floors and ceilings. In a cold climate a well-insulated building envelope will help in keeping the building cooler in the summer and warmer in the winter. In a hot climate natural ventilation will be of more importance though an appropriate building envelope is also necessary. Reduced energy consumption provides financial benefits for the building owners and helps reduce the carbon dioxide footprint of the building on the environment.

- Is the building designed for health and wellbeing of occupants? This means that the building will be pleasant and safe for people to be in. It could contain the elements of intuitive floor
plans, spacious and well lit circulation spaces, fresh-air circulation and monitoring units, dampness and temperature controls. It also means use of people safe materials and pleasant architectural design that provides psychological and physiological benefits for human occupants.

• A passive strategy precedes every other issue, which means taking natural ventilation, natural lighting and other passive technology strategies for solving the bulk of the problem of energy conservation. Then the remaining problems of building energy conservation can be accommodated through an active strategy. An active strategy should be optimized to improve energy efficiency.

• Appropriate Technology (AT) must take precedence over all other technical measures wherever possible. AT does not necessarily mean low technology. As long as a shortage of resources exists AT will be important, as many of the poor in the world understand. Today, the OECD web site equates "appropriate technology" with "environmentally sound technologies." The United Nations' "Index to Economic and Social Development" also links "appropriate technology" to "sustainable development." If mega-event buildings are under obligation to showcase environmentally friendly design AT should be one of the analysis criteria.

• Are there display and celebration features that a mega-event building must possess to make it a good design? The basic functionality of this type of building includes a variety of tasks like education and services to the audience, and enough space and flexibility to fit events, as well as offering the audience continued pleasure with good light and ventilation.

• Is there an overall consideration to solve the problem of post-use satisfactorily? This should contain the specific measures to be taken after the end of the mega-event, to consider the whole life-cycle of the building by using the 3Rs principle (Reduce, Recycle, and Reuse).

10-3 The Current Trend of Mega-event Buildings is not Green


The principles of green building are typically based at a set of values and beliefs, but their core is reducing the environmental impact of buildings. This underlines the need to be environmentally responsible and resource-efficient throughout a building’s life-cycle, from siting to design, construction, operation, maintenance, renovation, and demolition. This requires close cooperation within the design team, especially between the architects, engineers, and client at every project stage. Green building practice expands and complements the conventional building design concerns of economy, utility, durability, and comfort. In this sense, almost every mega-event building, built before the 1990s, was often far from striving to be green.

Firstly, in terms of the construction process, most conventional mega-event buildings were taken step by step through site planning, architectural design, construction planning, the bidding or tendering process, construction, commissioning, and then put into operation with each stage only considered independently. The owners were not part of the management of a linear process to manage the design team and builders. According to the traditional process, they assigned the tasks to a design team, and then the design team distributed its finished drawings to the construction team, and the construction team would do exactly as the drawings stated under the supervision of the owners. This traditional practice continued until the concept of sustainable design started to become the consensus in the 1990s.

Arising out of an awareness of inefficiencies in the conventional design and construction process and an increasing client demand for adherence to budgets and contracts, Integrated Project Delivery (IPD) is an important element in reaching the goal of green building design. IPD is an innovative contract mechanism that offers an alternative to the usual design-bid-build process or the design-build approach. More than just a contractual method, IPD aligns a whole systems approach to design and requires early involvement of the site planning, design and construction disciplines to be successful. LEED (Leadership in Energy and Environmental Design), the building labeling tool developed by the US Green Building Council, is intended to improve building practices through transformation and innovation, and therefore requires traditional methods of design and construction be changed and modified. IPD is an example of such a change.

IPD is not only a legal framework that the owner, the architect, and the builder can use to collaborate on a design and construction project. Specific IPD contract documents have been developed by several
organizations, including The American Institute of Architects (AIA), which released in May 2008 a version of IPD that joins the library of contract templates the organization publishes. This is seen as an indispensable part of green building that has the potential to change the building industry significantly.

If it is hard to distinguish between conventional and sustainable mega-event buildings judging only from the design and construction approach, it is possible to say that conventional mega-event buildings are not green because there has been very little work to ensure their environmental impact. A case in point is the Dutch Pavilion at the Hannover 2000 exhibition. Although designed according to green principles, because the building had a life of less than a year a life cycle analysis of its impact shows it is much worse than a conventional office building.435

It is also possible to take a close look at where mega-event buildings have been located for further consideration of this type of special building which often presents the following characteristics.

1) Although the premier purpose of mega-event buildings is not entertainment, the features of a mega-event have evolved passively from a simple industrial production exhibition into a comprehensive urban activity. This expansion is also part of a trend that finds spending on leisure and entertainment increasing as never before. So, their predominant characteristic of entertainment architecture can be easily recognized through their visual aspects, such as playful re-creations of famous monuments, enormous statues and fountains, and some stylistic features, such as elements of postmodernism. This has nothing to do with making green buildings.

2) The architecture of mega-event buildings could fall into the category of festival architecture which has brought vivid color and sensory delight to the host cities. Festival architecture has allowed architects to experiment with new ideas, new forms and new spatial arrangements.

3) Mega-event activities are ephemeral, so the halls on the site of an exhibition are often intended to last only for a couple of months. It is inappropriate from certain angles that the large-scale display facilities required for a short period of time could be considered for permanent or long-standing uses, particularly in cities. Such large buildings can be inappropriate for a human scale and urban fabric, although not necessarily when it comes to entertainment activities.

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Because of these characteristics, many mega-event buildings have tended to show symbolic meaning more than function and have used a multidisciplinary and performance based approach to exhibition pavilion design. It is not to criticize the significance of this, but to state the fact that its practical function is thus trivialized, which makes it difficult to find uses for such building once the event is over.

It is not enough that a good mega-event building has an unconventional external form as it also has to be fit for purpose. Furthermore, “they are insanely expensive. …… There are few things less sustainable than building several billions worth of structures that will last a few months”. The UK Pavilion at the 2010 Shanghai mega-event cost a reported 25 million pounds (27.5 million euros). Some other bigger investments were the US Pavilion with a budget of US$61 million, the Australia Pavilion which cost AU$83 million, the Japan Pavilion which cost US$140 million, the Saudi Arabia Pavilion that cost US$160 million and the cost of China's pavilion of 2.35 billion Yuan (about US$360 million). Most of these pavilions would follow prearranged contracts and be dismantled after the event.

Almost all buildings on the site of the 2010 Shanghai World Expo declaim themselves as a “new green energy-conserving pavilion” based on a variety of ways to add green technology components to the building or even something green to the design concept. Green seems to have become the most popular part of the environmentally aware building vocabulary. Although so many venues have claimed themselves to be green, how many are there that really are?

The mega-event building can be checked against the core idea of green building, which is efficient use of resources, to make an assertion that current event buildings are not green. Based on the common objective of green buildings to reduce the overall impact of the built environment on human health and the natural environment, the justification can be easily reached that most mega-event buildings are not green, and have not been so throughout the history of mega-events. Summarizing the measuring standards regarding green building, these consist of:

1) Efficiently using energy, water, and other resources

2) Protecting occupant health and improving employee productivity

436 Rowan Moore, *British Pavilion; Chelsea Barracks*, www.guardian.co.uk › Culture › Art and design › Architecture, 25 April 2010

437 Text proper in Chinese: 世博投资上亿展馆多数将在会后拆除，2010-04-13，来源：大洋网-广州日报(广州)

438 Text proper in Chinese: 陆文军，上海世博会引领中国绿色建筑理念，2010-06-13，来源：新华网
3) Reducing waste, pollution and environmental degradation.

For mega-events only the first and last criteria are really relevant but these reveal that most mega-event buildings fail to reach the standard required for green building.

A mega-event may bring some economic benefits to the host country, but too many venues are set too close together, and the large size of the venues or having venues with too discrete a layout makes it difficult to adapt them with ease so that they keep a high-frequency of usage. If the building cannot keep running in a sustained way, it is unable to support its large management and maintenance costs, and long-term energy waste is then certain to happen. To avoid such phenomena, most mega-event halls will be dismantled after the events and only a handful of them become the legacy or memorial of events. There is a huge investment in steel and concrete supports for just a few months of the event. It is a paradox that even mega-events that have spared no effort to promote green ideas, like Hanover 2000, come with enormous energy consumption because of their short-term activities.

10-4 Mega-event Buildings as Measured by the LEED Assessment Tool

As the world's most influential green building assessment system and one of many means to promote environmental design, the LEED rating system implements a points system, mainly focused on saving water and energy, reducing carbon footprint through encouraging use of public transport, improved indoor air quality, and using environmentally friendly materials. It has become the template for all nations to establish the evaluation standard of green building and sustainability.

Although the LEED Rating System for New Construction is designed to guide and distinguish high-performance commercial and institutional projects, it is hard to find a place for rating a mega-event pavilion. On the other hand, it is not necessary for the ephemeral pavilions to apply for LEED certification because the cost of the construction of a green building is huge, and the entire LEED certification process is too costly and cumbersome for projects of this scale.

LEED certification is worthwhile for permanent developments at a mega-event site or for mega-event like activities, such as world games events. The 2008 Beijing Olympic Village, was the first LEED-ND project in China, and featured a number of LEED Platinum buildings. Buildings featured technologies like an integrated ground heat pump system, solar collectors, advanced envelopes, day-lighting systems, natural ventilation, and green lighting. The ground-based greywater heat pump
system reduced natural gas energy usage by 30 percent, which translates into hundreds of thousands of cubic metres of gas saved. However, this was the Olympic Village, which is residential in scale, rather than the games venues themselves.

The 2010 Shanghai Expo Centre is designed as a contemporary model of energy efficient and environmentally friendly building from a technical point of view. The design plan introduces the 3R (Reduce, Reuse, Recycle) philosophy, and gives an overall consideration to resource use and energy saving, recycling and reclamation, in order to control the consumption of resources and energy, reduce the amount of pollutants discharged, and minimize the impact on the environment. The building was awarded a LEED Platinum certificate. However, the number of LEED certified event buildings is small and although this approach may be suitable for more permanent facilities, like those built at the Olympic Games, this may not hold true of mega-event buildings in general.

**10-5 Why a Kit-of-Parts (KOP) Structure is the Greener Solution**

At first glance KOP structures are buildings with some advantages, but with closer scrutiny more subtle advantages become apparent. Being flexible and changeable to suit different sites, the KOP structure will offer opportunities for reclaiming and reusing single elements, parts and components. This can provide a strong environmental option not available with many other buildings designed and constructed using a conventional approach.

One unique advantage of KOP structures is that at the end of their useable lives, they can be dismantled into many pieces or single elements. While most metal in kit-of-parts structure is a true “cradle-to-cradle” material in that it can be recycled multiple times with no loss of material properties, it is also a high reuse material as it can be reused multiple times prior to being recycled. Obviously, this recycling of metals is a way of reducing pollution.

As already indicated, KOP structures demonstrate their sustainability by circular use of their elements or parts, thus achieving a much longer life cycle than other kinds of buildings. The advantage of a reclaimable and reusable KOP structure in association with LEED Credit MR 3 was analyzed as follows:

*Using reclaimed elements is an effective strategy to reduce the environmental impact of a building by eliminating the energy required to recycle scrapped metal into new structural sections. The*
United States Green Building Council (USGBC) has recognized the value of reused components through LEED Credit MR 3 – Materials Reuse. One or two points will be awarded, respectively, if the project can demonstrate that 5% or 10% of the total monetary value of materials on the project is reclaimed, refurbished, or reused. This credit applies only to materials permanently installed in the final building. The LEED Reference Guide for Green Building Design and Construction lists possible strategies for obtaining points for this credit. Salvaged, refurbished, or reused beams, posts, flooring, paneling, doors and frames, cabinetry and sometimes furniture can be applied to this credit. As prominent as LEED is, garnering the MR 3 credit should not be the ultimate goal for incorporating reused steel. In fact, only a small percentage of all LEED Certified projects have been able to obtain this credit. Salvaged materials are being incorporated into many projects without the recognition of LEED Certification, simply because it is the environmentally preferable option.

In short, KOP architecture demonstrates the following green fundamentals:

- Circular economy will be achieved by coupling maximum waste prevention with material recycling
- It is flexible and changeable to suit different venues
- It includes reconfigurability
- It maximizes reuse of land and surroundings
- It ensures maximum building life span, and hence minimal overall embodied life-cycle energy.

10-6 Green Score of Kit-of-Parts Structure

If calculating the green score using the LEED rating system, the KOP structure has a relative advantage for the following parameters with points inside the brackets indicating the potential possible score:

- Site Selection (1)
- Alternative Transportation—Public Transportation Access (6)
- Development Density and Community Connectivity (5)
- Site Development—Protect or Restore Habitat (1)
- Site Development—Maximize Open Space (1)

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439 Erika Winters-Downey (2010), Reclaimed Structural Steel and LEED Credit MR 3 – Material Reuse, Modern Steel Construction, May 2010
According LEED 2009 for New Construction and Major Renovations, being certified needs 40–49 points. The KOP structure, as long as it meets the above criteria which are directly relevant to a kit-of-parts approach, will easily be awarded a green certificate from LEED.

10-7 The Design Approach of Hybridizing Kit-of-parts Structure (HKS)

Figure 10-1 sets out a flow diagram, for the kit-of-parts approach to building. The following section explains what is meant by ‘hybridization’.

10-7-1 What is the design approach of HKS

Most architectural professionals have long thought of creating spaces as one of the starting points in the approach to architectural design and have seen the spatial effect as the goal of the art of architecture. The proposed kit-of-parts structure is attempting to stimulate a shift in the pursuit of a building’s ability to be renewed and reconfigured. The key to this new approach is first to design
individual flexible components and elements to suit the type of building as first required and then to prioritize these individual elements so that the needs of the following or secondary projects are met.

What counts most is that this process is quite different from the conventional space-oriented principles of design and much more like the process of industrial or product design. This is what is meant by hybridization, as it is a marrying of architectural and industrial design processes. The process of design for a HKS could be as shown in Fig.10-1.

10-7-2 Special merits of design using HKS
The preliminary preparation works for design and construction have much in common with conventional architectural design but there are differences. The key differences of the HKS approach are:

1) Design of parts and elements for re-use. Based on an overall analysis of conditions, all materials selection is done with regard to the flexibility, reusability and rigidity of the elements.

2) Design of parts and elements for assembly and combination, together with the necessary interconnecting pieces. At this phase of the research and analysis the focus will be on how to bring into effect the arrangement of various parts, and how these can be disassembled and then assembled again to form a new structure with appropriate aesthetics.

3) The feature of KOP is reusability. As a modified model, HKS in the design of first round measures is aimed at subsequent usage, which should be considered in parallel with measures for the first round. In this way, renewability and a number of whole life cycles can be ensured.

These three phases of design are pivotal steps to achieving the goals of a building’s ability to be renewed and reconfigured without violating the needs of the users as well as the fundamentals of the circle for future usages. The first phase is more like industrial design and the second is more like mechanical design. Both the normal products of industrial and mechanical design can be used anywhere without necessarily connecting to the conditions of the local environment. However, the end-product of HKS should be finally located in a certain venue or environment. So HKS has to be
universal but place specific at the same time. As a sustainable building system, HKS’s parts and elements should inherently contain interrelationships with the vernacular environment.

10-7-3 Remaining life-cycle of HKS after the first round

Because the current architectural aesthetic value of mega events buildings gives priority to the needs of first round usage without due consideration to second tier or after event re-use, this needs to change for a green building to result. After the first round of its usage, the HKS can be continued to be used in various ways as follows.

1) The whole, parts, or elements can be used for the same size or smaller events in other venues.
2) The first round event building can be split into several small buildings, thus, breaking up the whole into parts to start a new life cycle.

3) Disassembling the first round event building into elements and reusing them for other purposes or occasions which need many repeated components with general specifications, such as telephone booths, bus shelters even residences.

By serving the event and city in the three major forms above, HKS realizes its maximum life-cycle potential and at the same time, it successfully switches from an ephemeral building to a more dynamic legacy in the cultural sense, being more sustainable than the current expensive ‘white elephants’, typical of many mega-events buildings.

10-7-4 Design for disassembly and green design

Since mega-events buildings are essentially temporary constructions, taking Shanghai 2010 Expo as an example, its total buildings account for a considerable area of some 1,657,200 square metres. Among the buildings, the area of temporary pavilion venues reached 1,053,000 square metres, which accounted for 63.5 percent of the total land. Different strategies for reducing environmental impact have been taken in this expo. Demountable buildings are found in the pavilions of the United Kingdom, Australia, Finland, China Beijing and Norway; low technology with natural materials are found in the pavilions of Spain, Brazil and China; and high-tech with use of biodegradable materials in the pavilions of Japan, Germany and Finland. All these pavilions were designed and constructed in accordance with the removable design standard, and reuse and degradation of materials were considered in the design. For example, steel components using rivet and screw connections instead of welding, in order to split the construction easily at any time. Thus, these pavilions can be taken to pieces and transported as single units to other places to be used again after the end of the Shanghai World Expo. Another example is the external walls of the Swiss Pavilion which are made from soy bean fibre that can end its life cycle in a safe and pollution-free way at the end of the exhibition. The Shanghai World Expo organizers’ ideology of accomplishing a movable exhibition has, to an extent, been achieved. The pavilions mentioned above are examples of using subtle design to attain certain sustainable aspirations. They have

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440施丁伟等 (2010), 临时建筑与世博会, 第一届全国高校土木工程专业大学生论坛论文及创新成果集, 同济大学出版社

441Sciences et Avenir, January 2010
successfully achieved the anticipated results of relocation. However, there is still room for portable and demountable buildings to improve and further research is needed.

- An essential requirement of an event building is to meet the changing needs of the event and visitors instead of being a structure which once being completed is then fixed and unchanged for ever in the traditional sense. Given this, all events buildings should be capable of change as well as being demountable.

- One of the basic design concepts of a green building is return to nature, which emphasizes that the exterior of a green building integrates with the surrounding environment, so that the natural ecological environment is protected. Obviously, a portable or demountable building is currently not equipped to handle dynamic interaction with its surrounding environment.

10-8 KOP – Reexamining the Interaction of City and Building

The interaction between mega-events and the host city calls for appropriate forms of event building to form a reciprocal relationship. As shown in Figure 10-3, comparing the major factors of economics, technology and environment, HKS excels two types of event buildings. Obviously, the HKS is in a state of forming a virtuous cycle with the host city through its multi-time usage. In this regard, the future development of the city will be benefited greatly. The HKS is specifically made to be a “reactive intermediate” between the mega-event and the city.

Financially, Figure 10-2 below is a comparison of the relationship between sustainability, mega-events, the city and three types of events building.

<table>
<thead>
<tr>
<th>Type of Building</th>
<th>Investment</th>
<th>Land</th>
<th>Materials</th>
<th>Maintenance</th>
<th>Deconstruction</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-off</td>
<td>low</td>
<td>none</td>
<td>high</td>
<td>none</td>
<td>high</td>
<td>none</td>
</tr>
<tr>
<td>Permanent</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>none</td>
</tr>
<tr>
<td>HKS</td>
<td>medium</td>
<td>none</td>
<td>medium</td>
<td>medium</td>
<td>low</td>
<td>high</td>
</tr>
</tbody>
</table>

Fig.10-2, Qualitative comparative analysis regarding construction cost for three types of event building

As the concept of urban sustainable development is still apparently stuck in ideas that put stress on materials and energy recovery after the end of mega-events, it is essential to look at the macro level, or

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442In chemistry a reactive intermediate is a short-lived, high energy, highly reactive molecule. When generated in a chemical reaction it will quickly convert into a more stable molecule.
Fig. 10-3, comparative interaction between host city, mega events and three types of event building for the major factors of economics, technology and environment. The arrow indicates direction and the number of arrows reflect the dynamic level of forces.

the connection between the event site and future urban development. Examining the interaction between a city and its buildings shows the city is motile and proactive and can be seen as the main body, while a building is a passive object, that is trying to remain unchanged, hence the interest in urban heritage buildings. Whenever the subject body is dynamic and constantly updating, its associated object needs to change accordingly. Also, to a certain extent, buildings have to meet the needs of a variety of social groups for appreciation of beauty and the functional aspects of living, work and recreation. This
suggests that buildings should change as the psychological and aesthetic requirements of the social group change, and not remain in the traditional architectural sense of being fixed forever once completed.

People have become increasingly demanding of their buildings due to the improvement in public taste along with developing economies. Not only events buildings, but also some large public entertainment and commercial buildings that were originally conceived as permanent are forced to change functions as they cannot meet public or market demand and consequently lose money. This phenomenon is more pronounced in some economically developed cities. The reasons are partly related to a changing market but the conflict between constructions for fixed functions and changing individual needs cannot be ignored. If sustainable development is considered at the very beginning of project design with the right approach to adaptability that makes its functions meet the continuously changing needs of people, such a project could exist forever.

10-9 What are the Main Barriers to Using Kit-Of-Parts Design for Flexible and Demountable Buildings?

Kit-of-parts architecture has benefits, as discussed, but it is not a panacea. Mass-produced green design is often scorned because the out-of-a-box concept tends to be associated with trailer housing and other low cost building types. So although KOP techniques have been widely used in building construction, using the methods in a more aesthetic way could be difficult. Very few design professionals will consider that ‘Lego-style’ KOP buildings have any architectural aesthetic value especially when it comes to high-end mega-events buildings.

Kit-of-parts architecture needs to be synchronized with the design of mega-event buildings which always tend to be novel or outdo each other in the name of creativity or innovation. Since mega-events appear to be an irreversible trend of current and foreseeable urbanization, the research into kit-of-parts architecture will be meaningful, relevant and challenging. In any move to educate and engage the public and related stakeholders with establishing a better environment, KOP can teach people by its example of inherently reducing environmental impact through reuse of resources.
The KOP system is an excellent genre in green architecture in its own right. However, it might not interest all people. Because of architectural tradition and people’s preoccupation with possession, the significant building is normally designed as if for perpetuity. The aesthetic pursuit in traditional culture has exerted a gradual and imperceptible influence on ideas of modern design. So in a larger perspective, the KOP’s unique sustainability-oriented and future-focused design concept needs to exert a subtle influence on ordinary people and professionals. For this purpose, the exhibition of the system through its photographs, technical literature and illustrations will provide the best vehicle for changing people’s attitudes.

**10-10 HKS and the Sustainable Events Building**

Since the aesthetic features of KOP architecture are not favorably regarded, most applications of KOP concepts have concentrated on the construction and technology issues. At the high end of building types, such as mega-event buildings, KOP is still rare or nonexistent. However, as the idea of sustainable development is becoming ever more widespread, there are signs of increasing usefulness of KOP.

An innovative new program is attempting to bring the industrial design ethos to the scale of buildings. So called OpenStructures (OS) start from an open online warehouse of 3-D drawings of basic parts from where anyone can access them. From these plans, users then build components (a sink, for instance), join components to form a system (a kitchen), and assemble systems into structures (a house) (Fig. 10-3). For all the pieces to fit together, like Lego bricks, they must conform to a standard geometrical template. This is a 4 x 4–centimetre grid that acts as a common language or “open-source code.”

Fig. 10-4 presents the primitive beauty of a building through its simple frames made by using a KOP structure. Obviously, a mega-events building will need to work at a vastly different scale. A contrast is found in Fig. 10-5, the Renault Building, which shows technical skill, fluency, and style, such as would be required for mega-events buildings. The aesthetic of forms comes from their function, structure and simplicity, but this is still recognizably a KOP building. When effectively devised, linked and formed into an HKS there is an advantage for the aesthetics of a building structure formed through repeated components.

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Generally, HKS offers a great renewability which other kinds of building cannot match. HKS’s renewability forms a new design challenge, with a core of infinite combinations according to usage and materials. Such a system takes advantage of the replace-ability of structure and connecting components, flexibly combined, to maximize the recycling of limited resources. This is a huge revolution for the design industry related to mega-events, moving it towards sustainable building marked by a new approach of multiply integrated design.
CHAPTER 11 CONCLUSION

11-1 Mega-events Buildings can be a Waste of Public Resources

When this thesis was ready for printing (Dec 27, 2012), the Shenzhen Auditing Bureau finally announced the audit results of the 26th Summer Universiade’s financial balance of payments and venues construction. According to the report, it cost 13.99 billion Yuan to hold the Universiade but the total revenue was only 1.217 billion Yuan. Venue construction was responsible for 7.52 billion Yuan, safety measures required 4.49 billion and 1.986 billion Yuan was spent on supporting projects. Apart from money involved in scandal related to corruption the approximate structural expenditures for the venue construction as extracted from the details of the report are set out in Figure 11-1.

**Fig. 11-1, Statement ofthe 26th Summer Universiade’s expenditures on venue construction**

<table>
<thead>
<tr>
<th>Classification of construction</th>
<th>Number of venues</th>
<th>Planned total investment</th>
<th>Audit approved final amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>New venues</td>
<td>20+1</td>
<td>6.045</td>
<td>6.994</td>
</tr>
<tr>
<td>Renovated venues</td>
<td>31+1</td>
<td>0.473</td>
<td>0.429</td>
</tr>
<tr>
<td>Temporary sites</td>
<td>10</td>
<td>0.093</td>
<td>0.097</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>63</strong></td>
<td><strong>6.611</strong></td>
<td><strong>7.520</strong></td>
</tr>
</tbody>
</table>

Compared with the 2012 London Olympics where temporary venues formed the majority of events buildings, Shenzhen’s venues for the 26th Summer Universiade were dominated by expensive permanent construction. Because Olympic venues are mainly used for major sporting events and these do not occur regularly, having a single function, high cost, and poor capacity for easy maintenance and development have become common problems with stadia and sports centers. After the 1972 Olympics, the Munich Olympic Park had annual operating and maintenance costs that averaged US$30 million. The 1988 Seoul Olympic Park was smaller but still had an annual maintenance cost of more than

444 Text proper in Chinese: 关于深圳大运会财务收支及场馆建设项目审计结果公告，日期：2012-12-27, 来源：深圳市审计局公告
445 On Dec 2, 2012 Guangdong authorities announced that former Vice Mayor of Shenzhen Liang Daoxing, who had been in office during the Universiade, was under investigation. This makes him the fifth high level official in Guangdong Province to be embroiled in a scandal in just over a month. He had been in charge of organizing the event from 2007 to 2011, and was suspected of using it for corrupt activities, according to the China Daily. Before that the former Mayor of Shenzhen Xu Zongheng was given the death penalty with a two year reprieve for accepting bribes, which included some related to the Universiade, according to Economic Observer.
US$8 million. However, when it comes to the maintenance of Olympic venues, the most serious is the loss of the Sydney 2000 Olympic Games. Olympic Park in the year 2003 had operating expenses of AU$139 million, only AU$54.43 million in revenue, and a loss of AU$85.39 million.\textsuperscript{446} A paper attributed these problems to “…a sprawling and windy entity somewhere between Sydney and Parramatta, in want of people and events, that lacked plans to attract business following the 2000 Olympic Games.”\textsuperscript{447} The park is operating in the red which can be seen in Fig. 11-2, where on a visit in September 2011 there were only four people in a carriage on the special line from Sydney Olympic Park to downtown Sydney. After both government and the private sector had invested a considerable sum in building not just sports facilities but also new hotels and a convention centre this seems a terrible waste of resources. The Olympic Park’s size is similar to that of the Sydney CBD. The efforts spent on its transformation and commercial development in recent years have been impressive: “Some 1.4 million square metres of new construction is planned for the Sydney Olympic Park by 2030. By then the workforce will have increased from 11,000 permanent workers – almost doubling the number in 2006 – to more than 28,000, and the precinct will accommodate some 14,000 residents.”\textsuperscript{448} If this is the case, the Sydney Olympic Park will only start to operate at full load 30 years of the opening of the Sydney 2000 Olympic Games, which will be halfway through the life of some of the buildings. Even if the depreciation costs of long-term assets such as these huge sports facilities can be ignored, the maintenance costs of 30 years of under activity are still very large. This does not conform to the principles of sustainable development.

It seems that when a major event is over most of the buildings become a problem of redesign, maintenance, or disposal. Although such buildings look impressive they are in fact nothing more than expensive stage sets. As a further example, among Shenzhen’s 21 new venues, there are 10 located in primary and secondary schools which is a satisfactory use for them. Most of the major venues have realized the need to open for public, but except for weekend peak hours, the usual venue visitation rate is not high. An assessment of the operating costs for the Shenzhen Universiade Sports Centre (Fig. 11-3) shows that its annual income is about 20 million Yuan, but the annual cost for utilities, property management, and labour costs totals 50 million Yuan.\textsuperscript{449}

\textsuperscript{446}gangtie5.com, 02 August 2012 ~ 0 Comments, Bird’s Nest annual maintenance costs of up to 80 million luxury rifle difficult operating

\textsuperscript{447}Red Dwyer, Olympic Park start to run, issue 4 August 2011, Western Sydney Business

\textsuperscript{448}Cover Story – Boom of Sydney Olympic Park, Olympic Park transformation, issue 4 August 2011, Western Sydney Business

\textsuperscript{449}Text proper in Chinese: 深圳大运会场馆赛后利用不足维护成本高昂，南方日报，2012年07月09日
Idle facilities are also happening at expo sites. After being busy for several years, the exhibition spaces of the Hanover World Expo 2000 are no longer as busy as in the past, and it seems the value of the land on which it sits is not to be fully realized. A large number of pavilions have been abandoned or are standing idle, and the progress of rebuilding the stadium is slow due to lack of investment. The large numbers of vacant buildings and parking lots have been likened to a leaky faucet, as these fixed assets are depreciated in vain, with no rent being credited to the balance sheet.\textsuperscript{450}

This is not a sustainable situation. Evidence from visits to North American Expo and Olympic sites also demonstrates the waste of resources in buildings that are no longer required, as very few mega event buildings have survived and found new uses.

11-2 Exploring the Final Processing of Mega-event Buildings

Unlike ordinary buildings, most mega-event buildings are designed for a very particular purpose, often a few exclusive activities. After that, the buildings are inevitably confronted with demolition, preservation, relocation, or a change of use. However, where these buildings are in the form of clear space, large span structures, these can have temporary uses for exhibitions but can be covered later for other uses afterwards. This suggests that the form of the events building affects its later potential of reuse.

11-2-1 Demolition is a frequently performed operation

\textsuperscript{450}Text proper in Chinese:梁雨霞：世博会修建场馆规划应当吸取德国汉诺威的教训，第一财经日报 2006 年 11 月 28 日
It is obvious that very few exhibition buildings are permanent as most are demolished. From the examples in this thesis it is possible to see that the ‘death’ of mega-buildings generally results from the following factors:

- Poor physical condition due to lack of continuing use that results in poor maintenance.
- Long-term vacancy which leads to high maintenance costs.
- Various failures of planning and construction authorities that interfere with possible normal use.
- Poor appearance without beauty or spiritual meaning.
- More financial value from new development.

Demolition is a highly controversial measure of the success, or lack of it, of events buildings. As discussed before, C&D waste is very harmful to environment. However, over and above this, mega events often feature high end engineering and concentration of construction time which can together produce more C&D waste. Even ordinary demountable panel buildings generally only achieve a secondary material utilization rate of 45% to 60% after demolition, which should be contrasted with the near 0% recovery of materials from most one-off mega-event buildings. Taking the case of Shanghai expo 2010, about 37k-tons of construction waste was produced each day, a rate which is 3.5 times that of normal household waste production, and which also formed 30% of the total solid waste of the city. Special forecasts have pointed out that there will be 40 million tons of construction waste from all the expo projects in China, and it will cost 20 billion RMB to dispose of this. Another mega event host city, London, annually produces 20 million tons of garbage. Among this, 16 million tons is commercial waste, industrial waste and construction wastes, accounting for 80% of the total. The disposing of events buildings C&D waste reduces the sustainability and liveability of the host cities. All of these aspects can cause serious conflict with the current urban reality, and affect the host city’s future development.

11-2-2 Permanent buildings for mega events

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The qualities required for mega events buildings to be permanent are suggested below:

- They are appreciated by most people.
- They are already part of local history or landmarks.
- They possess special aesthetic value.
- They have good design with functional versatility.
- They have made use of special and meaningful science, technology, or materials for the construction.
- They have excellent practicality apart from their original purpose.

Fig.11-4 (left), the Royal Exhibition Building in Melbourne is the only surviving Great Hall that once housed a 19th-century international exhibition and is still used for exhibitions. Fig.11-5 (right), Please Touch Museum, the Children's Museum of Philadelphia was being renovated in August 2008.

In some cases a permanent events building is always an option, such as the Royal Exhibition Building in Melbourne (Fig. 11-4), which has been used for holding exhibitions since the 1880 Melbourne International Exhibition. This building has a large interior space which can be fitted out for exhibitions, but perhaps more importantly is an appreciated landmark, thus leading to its being retained as a permanent exhibition venue. In contrast, the Children’s Museum of Philadelphia opened on October 18, 2008 (Fig. 11-5). It is a newly renovated and expanded museum at the Memorial Hall in Fairmount Park, the former site of the Centennial Exhibition of 1876. This exhibition was the first major World’s Fair to be held in the United States and commemorated the 100th anniversary of the Declaration of Independence. Notably, in the context of this discussion, the museum’s new location, Memorial Hall, is one of the last remaining structures from the Centennial Exhibition of 1876.
The Memorial Hall is made of brick, glass, iron and granite and was designed in a beaux-arts style to house art exhibits during the 1876 Expo. Afterwards, it reopened in 1877 as the Pennsylvania Museum of Art and included the Pennsylvania Museum School of Industrial Art. Fifty-one years later the museum moved out. The Memorial Hall continued to house the school, and was taken over by the Fairmount Park Commission in 1958. The building was later used as a police station and has just been renovated to house the Please Touch Museum. The facilities and exhibitions at the museum are tailored to young children under 7 years old and family audiences to encourage intergenerational learning and inspire the imagination if children. To do this has required significant change to the Expo space which was basically for art works, leading to a total cost of US$85 million for the renovation and expansion of the Memorial Hall. Though it was a good art museum before the conversion, the impression is that the building has now been forced into a mould. It has also not been a total success. Only a little more than two years after moving from its original city centre home to the new more expensive venue in Fairmount Park, the Please Touch Museum has showed a drop in membership and attendance and has accrued debt payments that are large and growing. Probably the original idea could be admired for trying to keep a rare architectural artifact of the 1876 Centennial Exposition from sliding into irretrievable decrepitude, but unless the redevelopment is a success this goal will not necessarily be achieved.

There are many reasons that could lead to this situation, but one falls squarely into the field of architecture. The Please Touch Museum has exposed the fatal flaw of a fixed structure which is that it is very hard to alter when the situation changes. Although “Form follows function” is not an infallible law of architecture, as long as the building still fits the needs and activities of people it should basically be a tenable building. Under the circumstances of not changing the form but only shifting the function the adaptation may not be successful, even when significant amounts of money are spent.

Using another example from China, in 2002, as part of the development of the city of Shanghai and adjustment of a number of major roadways for the coming 2010 Expo, the Shanghai Municipal People's Government decided to lift the Shanghai Concert Hall 3.38 metres and move it 66.4 metres away from the city’s major traffic artery, Yanan Viaduct. Using a synchronous lifting system

454 Anna Hyclak, Parkside: Celebrating Philadelphia's Past and Future.philadelphianeighborhoods.com, Apr 30, 2010
455 Peter Dobrin, Please Touch Museum feeling pain from debt load, January 31, 2011, the Inquirer
controlled by a power loading control system (PLC), hydraulic cylinders lifted the 5,800 ton Shanghai Concert Hall uniformly, thus maintaining the structure's integrity, while moving it across a populated residential complex. In total fifty-nine hydraulic cylinders were used each with a 200-ton lifting capacity, to hoist the building from its original site. The whole relocation took six months and cost RMB 60 million. Considering the building area (2,558 square metres) and seating capacity (1,122), the cost of moving it appears small when compared with the cost of constructing the Shanghai Oriental Arts Centre, completed at almost same time, which was built at a cost of more than RMB1.1 billion. However, applying a comparison method and using buildings of similar grade, size and construction time, the conclusion (Fig.11-6) can be reached that the cost for the overall relocation outstripped the costs of rebuilding or even new construction at that time.

Fig.11-6 Comparison of Comprehensive Economical Indices of Chinese Concert Hall Built in the 2000s, data collected from published report and local newspapers.

<table>
<thead>
<tr>
<th>Name of venue</th>
<th>Construction type</th>
<th>Seating capacity</th>
<th>Total area (m²)</th>
<th>Total investment</th>
<th>Build date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shanghai Concert Hall</td>
<td>Relocation</td>
<td>1122</td>
<td>2558</td>
<td>RMB 60 million</td>
<td>2002–2003</td>
</tr>
<tr>
<td>Beijing Concert Hall</td>
<td>Transformation</td>
<td>1024</td>
<td>7210</td>
<td>RMB 38 million</td>
<td>2003–2004</td>
</tr>
<tr>
<td>Nningbo Concert Hall</td>
<td>New built</td>
<td>605</td>
<td>2676</td>
<td>RMB 55 million</td>
<td>1999–2003</td>
</tr>
<tr>
<td>Tianjin Concert Hall</td>
<td>Reconstruction</td>
<td>630</td>
<td>3500</td>
<td>RMB 24 million</td>
<td>2006–2009</td>
</tr>
</tbody>
</table>

As shown in Fig.11-6 the lifting and moving of the Shanghai Concert Hall was costly. A recently published graduation thesis from the Shanghai Institute of Visual Art indicated that its theatre facilities are old and because it has to compete with new facilities its business development is slow. This makes it difficult to recover the costs of moving it, so the financial pressures gradually increase and the building may soon become unviable.

From the Please Touch Museum and the Shanghai Concert Hall examples it seems that reusing old buildings for a different purpose, or even the same purpose, may not work. One of necessary conditions of green design is that it should suit differing conditions in terms of locality, time, use, and the people involved. This suggests a dynamically adaptable building to suit constantly changing urban

456 Text proper in Chinese: 上海建筑装饰（集团）有限公司，上海音乐厅装饰工程技术总结报告，
457 Text proper in Chinese: 中共中央机关报《人民日报》2007-2-9 日报道，用 11 亿元打造的上海东方艺术中心营运 18 个月来，各种豪华设施遭闲置，加上保养费高昂，陷入“建得起，用不起”的困境。
458 Text proper in Chinese: 上海音乐厅市场化模式初探——08 级文化产业管理专业徐豪洁毕业论文-复旦大学上海视觉艺术学校（SIVA）
circumstances and people. It is necessary to make full use of limited resources to cope with various changes, in the hope that subtle small changes to the building will mean it can cope with large variations in its use.

Because a building should serve society, as constituted by the people who use it or live near it, it has social attributes. From the view of building life cycle a building can also have historical attributes because it can last for decades, or even more. Besides, architects should consider not only the function of the building but also its urban and geographical attributes, which means keeping the building in harmony with the city and its context, including the context of climate. Because of rapid urbanization both in China and globally, the traditional attributes of many building are facing up to a new situation. Nowadays relocation or alteration of existing buildings is not uncommon in urban remodeling or because of the need to upgrade infrastructure. However, because of the cost, relocation is seen as a last option “Unless there is no alternative but to relocate”. Because of the limits of the original structure making alterations to buildings is always difficult, and often produces a result that is not as good as building new. Lack of flexibility to able to respond to change is a major disadvantage of many permanent buildings.

11-3 The Significance of KOP for Adaptive Architecture

In the second half of the 20th century, experiments made by architects such as G.E.A.M., Team X, Archigram and Cedric Price were based on the shared the belief that the most important thing for a building was for it to respond and adapt to a constantly changing external environment, rather than being an eternal symbolic or traditional cultural object. Many of their works were provocative and pushed the traditional architectural boundaries by including the dynamic ideas of space and time, which reflected a pursuit of instability and variation in buildings.

The increasing demand for urbanization across the globe and the consequent construction boom has resulted in big impacts on the environment and natural resources. The speed of this development is making the urban fabric of many developing countries inappropriate for place and climate. The coming shortages of natural resources will mean that it is time to find sustainable solutions to alleviate the pressure holding mega events puts on these hard pressed cities.
Good architectural design must include a response to its specific requirements, situation and surroundings. Among these the specific program, site and social background define the basic design framework. The principle of adaptation should represent a paradigm shift in today’s architecture and planning: an adjustment in thinking that comes about as the result of new discoveries, inventions, or real-world experiences. Buildings need to move beyond being fixed objects to become something more transient and responsive, so that they match the pace of change in modern life. It is, therefore, odd that the demountable building with its focus on adaptable reuse has not been given enough attention. If architects can readjust to accept this adaptive mindset, then modern architecture could be poised to enter a new era of innovation and sustainability. This approach seems particularly appropriate of events buildings, with their initial transient use.

11-4 The KOP Approach and Sustainable Urban Development

This research was inspired by a very unique case study, the Black Yak Hair Tent in Tibet. The technical feasibility of this type of building has been investigated and explored, and has been shown to relate closely with the way of life of those living on the Plateau. For those designing buildings for mega events, this precedent can be seen as a model for the development of a modern kit-of-parts exhibition hall. In fact this approach of making exhibition buildings that are reusable, and made from local materials, can also be found in western architecture, such as the Swiss Pavilion (Fig.11-7) at
Expo 2000 in Hannover, Germany. As discussed earlier, this structure was recycled into the large wooden sphere known as *Le Palais de l'Equilibre* for Switzerland's Expo 2002 in Neuchatel. In its second use, this imposing structure housed a presentation illustrating the fragile balance between the world's economy, society, and the environment. The wood was cleverly crafted to provide a geometric sun shield around the outside facade of the sphere.

Although the materials and methods of these cases study buildings are different from the BYHT, both types of exhibition building have the same sustainable approach for trying to minimise the impact on the environment. In retrospect, almost the same type of design can be found in Archigram, such as the Kassel Kit event-structure (Fig.11-8) for Documenta\textsuperscript{459}, in 1972. This was a temporary art event and stage set up using a kit of parts based on the Instant City kit created by Peter Cook, Dennis Crompton and Ron Herron. In addition some of the recently finished 2012 Olympic venues in London manifest the same approach in terms of their potential disassembly. The benefits from using this system of building can be stated as follows:

- Layout freedom is added to the building system.
- A building is constructed that can be adjusted depending on the weather, the terrain and its features, location and requirements.
- Reusable foundations, components and construction materials means local environmental ecosystems are not damaged.
- Achieving a completely dry building method, with no wet materials such as use of concrete becomes possible.
- Adjustable components and flexible display spaces can be reconfigured as needs change.
- The lasting impact of this kind of building is leaving almost no trace on the venue after the mega events.

With the rapid development of urbanization and as urban problems are becoming increasingly apparent, seeking sustainable urban development has gradually become the focus of sustainable human development. The overall objective of the Agenda 21 for the sustainable development strategy for a city is to improve the urban social and economic environment, and the quality of life and

\textsuperscript{459} Originally, as part of the Bundesgartenschau (Federal Horticultural Show), Documenta is an exhibition of modern and contemporary art which now takes place every five years in Kassel, Germany. It was founded by artist, teacher and curator Arnold Bode in 1955.
working environment of its citizens. In accordance with the theory of sustainable urban development, its targets are to be achieved under the premise of maintaining the normal functioning of urban areas, sustained economic growth, social progress, gradual optimization of the quality of life, and continuous improvement in the level of urban modernization. This is done to achieve the sustainable use of resources, ensure environmental quality continues to improve, and to allow sufficient conditions for the future development of the city and the space around it.

As a potential catalyst of sustainable urban development, the goals of mega events and construction should include issues such as conservation of energy resources, protecting the ecological environment and creating a better living environment for people. From the point of view of development, an appropriate mega event can be the vehicle for the implementation of sustainable urban development. Sustainable urban development, from the urban dimension, plays the role of regulation and controlling the process of development of events on a scientific basis and, given the vast human and material support necessary for holding mega events, the two need to be seen as interdependent and unified. The correlation between the indicators of sustainable urban development and those of green mega events buildings are necessarily similar.

The indicator system of sustainable urban development can also be used as a measure against which to identify and display the status of sustainable urban development. Generally the indicators include energy and resource consumption, waste emissions, per capita living space and public green area, the quality of the air, and water quality indicators. Because the construction of a mega event is an important part of the city, the buildings set up around the big event should be based on indicators in the area of energy, water, land, and materials use, and urban sustainable development, showing there is a close link between both goals. If the BYHT is a kind of Appropriate Technology for relatively primitive plateaus, then KOP structures can be another kind of Appropriate Technology for modern cities. The two approaches to shelter design have common ground between them as both play a dynamic role in dealing with their respective changing environments in a sustainable way. From the point of view of city building, a KOP building can contribute to achieving sustainable development in the following ways:

- Through the protection and recycling of natural resources can be relied on, especially the direct and indirect savings in use of limited arable land and other non-renewable resources.
• Through creating healthy, pollution free, convenient and comfortable ecological environments, and reducing and avoiding activities that consume energy and produce wastes.
• Through easing the impact of mega events on the host cities.

11-5 Social and Cultural Aspects of KOP Buildings

One of the fundamental principles of green building is humanism. Green building must be based on the human being, as habitation is a most basic need for human survival. Green building should meet basic human needs as both the fundamental starting point and destination, and also aid in achieving social equity. For events buildings to be green, humanity is also the necessary starting point. Compared with other approaches, KOP has an unparalleled advantage as an urban event building because it puts the relationship to people and their needs first. It also addresses these constantly changing needs through its inherent flexibility.

11-5-1 KOP offers Cultural Events More Freedom in Venue Selection

The deeper the process of urbanization, the greater the need to satisfy the spiritual and cultural desires of people. This has produced corresponding requirements for a greener environment, inclusion of more nature in cities, and provision of spaces for holding cultural activities. The more important the event is, the higher the requirement will be. In fact, development is often prohibited in areas with heritage building, rich greenery and history. The one exception to this could be KOP buildings, as these will not damage the environment during constructing and use. City greening is a natural condition needed for a high quality city or public space, and these areas are also the first choice for sites for holding events and activities. In fact, heritage building, rich greenery and history have been the necessary conditions for the best venues to hold events.

In 2008 the structure being erected in the McCarthy Quad of the University of Southern California campus was for the Grammy Foundation's annual signature gala night (Fig. 11-9). McCarthy Quad is a broad green expanse between the Doheny Memorial Library and the Leavey Library. The building had to be demountable, as otherwise this leading private research university would not have allowed a stage for popular music to be set in such a precious green space. Another temporary use of a green space is seen in the presentation of Shakespeare in the park, in London (Fig. 11-10). Here the stage is a simple construction but scenery is minimal because of the luscious backdrop of the park greenery.
Another type of demountable stage is seen in the Grote Markt (Grand Place) the central square of Brussels (Fig. 11-12). This square is surrounded by guildhalls, the city's Town Hall and the Breadhouse. The square is the most important tourist destination and landmark in Brussels and is a UNESCO World Heritage Site. Holding events in such places is recognised as being important: “Events in historic places make a vital contribution to the economic sustainability of our heritage. They add to the enjoyment of countless visitors at a huge range of sites, from urban squares to open countryside, as well as generating an important source of income.”

A city needs high quality public spaces but in turn these need activities and events to keep them alive, and such events need temporary structures. Using the KOP approach for such events buildings and structures that will not permanently occupy urban public space, means there is no footprint left at the end. Therefore, KOP buildings and structures could play a positive role in promoting cultural activities. It might even be that KOP structures from a mega event could later be used for promoting such events in public spaces in the host city.

The neglect of the public domain and the human spirit in the era of the Industrial Revolution created a group of buildings often stereotyped as forest of steel and concrete, virtually becoming a standardized urban development model. Rapid urbanization further leads to a large number of urban public spaces being invaded and occupied, and what public space remains is surrounding by structures that are out

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461 Will Holborow, et al., Temporary Structures in Historic Places, English Heritage, September 2010
of scale with it. This lack of personality in the space means it is difficult to get a sense of place, and this in turn can lead to a kind of loss of self. What is needed is a KOP architecture that not only sits lightly on the earth but is also conducive to the preservation and continuation of the history of public space through a sense of easy identification, and spurring on the formation of a strong sense of place.

11-5-2 Returning urban public space to everyone after the event

Urban public space is mainly used by low-income groups including socially disadvantaged groups. Rich people have their own spaces, with swimming pools and golf courses that they pay to use. However, real public space is used by the majority of ordinary people. From the social level, being people-oriented means meeting everyone’s right to life, and also respecting the right of every person for freedom, equality, and fair development. Moreover, the right of everyone to use public and natural resources should be respected. Social public and natural resources belong to all the people of a society and not just a particular social group or single person, so when a small group of people have more than their fair share of these, this violates the rights of other to use the same resources. This is not only contrary to the principle of social justice but also to the basic “people-oriented” value orientation. When an events building in a city public space is empty or occupied by a person or group, it will eventually been taken as their private possession, and will no longer be “public”. This is unfair to the whole of society.

The high strength of development created by mega events tends to ignore the public interest and misappropriate public places, resulting in an upset in neighborhood relations which can result in apathy and loneliness, or social stratification and further exacerbation of isolation. The KOP approach, because of its high degree of flexibility towards the needs of different races and income levels, can provide a container for a variety of different occasions and places, and one which could produce a variety of atmospheres. A KOP building will not damage the environment, as city public space could return to the original green areas, squares and sports space when it is removed after the event, reflecting the people-oriented concept of green building and a green city.

11-6 Further Study

Since holding mega events appears to be an irreversible trend of current urbanization, this thesis argues that research of kit-of-parts architecture is both essential and full of challenge. With a focus on
the feasibility and implementation of KOP structures, this thesis has touched upon a neglected field of architecture, but it is as yet far from being a monolithic body of theory.

In this thesis, all enquiries into North American expo sites and studies of major events in China, especially in Shanghai, have shown that the modern method of exhibition building procurement is not sustainable. The survey undertaken of both professionals in the exhibition industry and the public has revealed that people are concerned about short lived events buildings, and are also increasingly in favour of a new type of temporary exhibition building. The descriptions of the case studies in this research suggest that temporary buildings are achievable, especially through maintaining the reciprocal principles of the whole structure, and that these need to be combined with flexible use of public space in urban environments. It has also been argued here that the kit-of-parts approach is the path to achieving these goals, while at the same time ensuring that not all temporary structures will have the same form. Such buildings will thus have a greater chance of being aesthetically acceptable to the users. Arguments have therefore been put forward to support the second part of the hypothesis.

The thesis has also identified opportunities for further research. The immediate need is to design and test an appropriate kit-of-parts for an exhibition structure that will be at the scale to fit in existing urban public space. As part of the testing a full life cycle environmental analysis will need to be carried out on the building. There is also a need for research to look at the ownership and governance structures of urban public spaces, and how these spaces have been and can be used in a more flexible way.

11-7 Looking Forward to the Future of KOP Structures

What is also apparent is that demountable buildings will lead to a new attitude to urban design and the effective uses of urban public space. The use of demountable structures for temporary events such as exhibitions will need land that is linked to good urban infrastructure. This suggests that there is a need to regard urban public space as something which changes its function over time.

The first major international exposition in 1851 used the existing Hyde Park as the venue for the original demountable Crystal Palace exhibition building. Once the exhibition closed, the building was moved to a new permanent site and the park returned to its original use. After that, other temporary
buildings have found a home in Hyde Park, such as the annual Serpentine Pavilions. This thesis suggests that this is the probable role for urban public space in a sustainable future. As a result, planning systems will have to change so that space use can change quickly and obtaining permission to erect temporary buildings will not be a long process.

The Crystal Palace of 1851 was a harbinger of prefabricated and demountable exhibition building. The hall of the New York's World's Fair held in 1853 was almost a copy of the Crystal Palace. The buildings were ushered in a new epoch in architectural history in terms of holding mega events in an urban environment. Since then this concept has not been in common use except for a few exhibition buildings. Among them the most noted are the IBM Travelling Pavilion, the Swiss Pavilion of Hanover Expo 2000 and the various invited designs for the Serpentine Gallery Pavilion start from 2000 to the present.

The global shortages of natural resources have given a new significance to these types of assembled buildings which hitherto have been poorly regarded. Looking again at some of the fundamental problems this approach entails could help in finding new solutions to other modern problems. Although almost 160 years have passed, the history of mega events buildings seems to be making a return to its original point; however this is not exactly the same as at the start because of all the knowledge gained in the intervening time. The Crystal Palace opened up a path towards an industrialized building system using prefabrication; the new type of KOP structure, HKS, will be not just be modern, but potentially revolutionary. It is suggested here that the use of new demountable buildings with their advantages will be part of a sustainable future.
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