SUSTAINABLE TIMBER PREFABRICATED ARCHITECTURE
IN SINGAPORE

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DEDICATION

To my beloved mother and father,

and to the people nearest to me.

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ABSTRACT

The role of the urban in addressing sustainability issues is becoming more widely recognized. The World Commission on Environment and Development (WCED, or Brundtland Commission) defines sustainable development as "development that meets the demands of the present without compromising future generations' ability to satisfy their own needs." This necessitates a careful balancing act between meeting human economic and social demands mainly through economic growth and preserving the environment and natural resources (Seetoh & Ong, 2008). Maintaining this delicate balance between development and the environment will protect future generations from gaining a standard of living that is at least as outstanding as ours. The overall goal of Sustainable Development Goal 11 is to make cities "inclusive, safe, resilient, and sustainable" (United Nations and Nations, 2014). Cities must now, more than ever, grow in an environmentally sustainable manner.

This paper gives a brief overview of timber prefabricated building system in Singapore, aims to achieve sustainable planning. The concept of prefabrication system has been proved in reducing to 52% of waste construction on to 35% of time savings on site. Economy, speed of construction and improved environmental performance are critical variables that challenge the modern construction industry to strike a balance between. Several case studies have been referred to obtain an in-depth appreciation of interest, in its natural real-life context. It was found that precast timber construction methods to be environmentally beneficial, and using lightweight modern engineered timber materials can reach excellent economic efficiency. As a result, there is an increasing demand for extensive assessments on the possible environmental benefits of prefabrication, particularly in the areas of built-in energy savings via waste reduction and improved material efficiency.

ABSTRAK

Peranan bandar dalam menangani masalah kelestarian semakin dikenali. Suruhanjaya Dunia mengenai Alam Sekitar dan Pembangunan (WCED, atau Suruhanjaya Brundtland) mendefinisikan pembangunan lestari sebagai "pembangunan yang memenuhi tuntutan masa kini tanpa menjejaskan kemampuan generasi akan datang untuk memenuhi keperluan mereka sendiri". Ini memerlukan tindakan penyeimbangan yang teliti antara memenuhi tuntutan ekonomi dan sosial manusia terutamanya melalui pertumbuhan ekonomi dan memelihara alam sekitar dan sumber semula jadi (Seetoh & Ong, 2008). Mengekalkan keseimbangan secara teliti antara pembangunan dan persekitaran akan melindungi generasi akan datang daripada memperoleh taraf hidup yang sekurangnya sama dengan kita. Matlamat keseluruhan Pembangunan Lestari 11 adalah menjadikan bandar "inklusif, selamat, berdaya tahan, dan lestari" (United Nations and Nations, 2014). Bandar sekarang, lebih dari sebelumnya, mestilah berkembang dengan cara yang lestari dari segi persekitaran.

Tesis ini memberikan gambaran ringkas mengenai sistem pembangunan pasang siap kayu di Singapura, yang bertujuan untuk mencapai perancangan yang lestari. Konsep sistem pasang siap telah terbukti dalam mengurangkan sehingga 52% pengurangan sisa daripada pembinaan hingga 35% penjimatan masa di lokasi. Ekonomi, kepantasan pembinaan dan peningkatan prestasi persekitaran adalah pemboleh ubah kritikal yang mencabar industri pembinaan moden untuk mencapai keseimbangan. Beberapa kajian kes telah dirujuk untuk memahami lebih mendalam tentang subjek kajian, dalam konteks kehidupan nyata semula jadi. Didapati bahawa kaedah pembinaan pasang siap menggunakan kayu bermanfaat untuk alam sekitar, dan menggunakan bahan kayu moden yang ringan dapat mencapai kecekapan ekonomi yang sangat baik. Menyebabkan, ada permintaan yang bertambah bagi penilaian yang lebih meluas mengenai manfaat daripada sistem pasang siap, terutama di bidang penjimatan tenaga melalui pengurangan sisa dan peningkatan kecekapan bahan.

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LIST OF ABBREVIATIONS

SGP 2012	-	Singapore Green Plan 2012
EMS	-	Environmental Management System
BCA	-	Building and Construction Authority
GM	-	Singapore Green Mark Programme
MET	-	Mass Engineered Timber
WCED	-	World Commission on Environment and Development
UNIDO	-	United Nations Industrial Development Organization
MEWR	-	Ministry of the Environment and Water Resources
PV	-	Solar Photovoltaic
DfMA	-	Design for Manufacture and Assembly
CLT	-	Cross Laminated Timber
LVL	-	Laminated Veneer Lumber
Glulam	-	Glued Laminated Timber
SCDF	-	Singapore Civil Defence Force
CITM	-	Construction Industry Transformation Map
PPVC	-	Prefabricated Pre finished Volumetric Construction
NTU	-	Nanyang Technological University
PDV	-	Passive Displacement Ventilation
SSA	-	Singapore Sustainability Academy
CSM	-	City Square Mall
SEAS	-	Singapore Sustainable Energy Association
PBU	-	Prefabricated Bathroom/Sanitary units
CTBUH	-	Council for High-Rise Buildings and Urban Habitat
DPM	-	Damp Proof Membrane
PSM	-	Peel-off Membrane
MSS	-	Miralite Side Sealer
IMCSD	-	Inter-Ministerial Committee for Sustainable Development
MCO	-	Malaysian Restriction Order

CHAPTER 1

INTRODUCTION

1.0 Background Study

Cities are becoming increasingly essential to an expanding number of people as a result of global and regional urbanization processes, and their impact on surrounding areas continues to grow as cities grow. Cities, in particular, are at the crossroads of potential and conflict between economic and sustainable development and the growth of affluence in newly industrialized countries. Cities' most important functions are tied to economic, social, and environmental factor (Flynn et al., 2016). The three pillars of environmental, social and economic, are related. Figure 1.1 shows how our economy and everything in our society is situated within, and entirely dependent on, our environment. This relationship means that any every influence or change in our environment will have an impact on society and the economy. As a result, any issue concerning sustainability must be evaluated holistically and realize this interdependence.

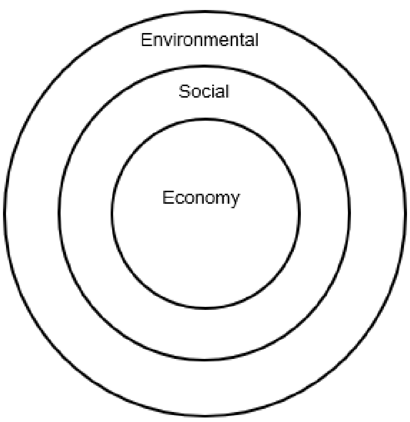

Figure 1.1 : The Three Pillar of Sustainable

Singapore, a developed first-world country, has a thriving economy and serves as Southeast Asia's financial hub. Construction, one of the industries that grows in parallel with the economy, contributes to environmental pollution and resource depletion over time (Yin et al., 2018). According to Tan & Abdul Hamid (2014), Singapore's environmental initiatives began in the 1960s with its annual Tree Planting Day, which has lately grown into a citywide awareness of the significance of urban ecosystems in achieving sustainability. Following on from Singapore's early accomplishments in recognizing the importance of greenspace planning in creating a sustainable city, (P. Y. Tan et al., 2013) Singapore's government has worked hard to establish policies and guidelines for the design and construction of sustainable buildings. The Singapore government is dedicated to become a global leader in developing a sustainable built environment, in addition to promoting awareness and addressing environmental sustainability.

1.1 Problem Statement

Over the past four decades Singapore, a small island metropolis with an ever-increasing and dense population, has experienced environmental management issues resulting from fast industrialization and economic development, threatening its sustainability and liveability (Fujii & Ray, 2019; Yin et al., 2018). Referred to United Nations & Nations (2014), the world's population is rapidly urbanizing, with 70% of people living in cities by 2050. Building energy consumption is on the rise, owing to rising population and per capita consumption, particularly in urban areas. Between 2005 and 2016, residential energy usage in Singapore grew by 25% (Department of Statistics Singapore, 2018). These reasons, among others, indicate to the need to examine sustainable building design more closely (Lan et al., 2019).

1.1.1 Physical and Environmental Changes towards Sustainable Planning in Singapore

To support sustainable construction, Singapore has established several initiatives and legislation such as the Sustainable Construction Master Plan 2008, Singapore Green Plan 2012 (commonly known as SGP 2012), Green Mark Scheme, and environmental management system (EMS). These initiatives have emphasised not only energy efficiency, but also the employment of a comprehensive strategy to support green building to ensure that environmental quality and comfort are not jeopardised.

In January 2005, Singapore's Building and Construction Authority (BCA) launched the Singapore Green Mark programme (GM), which assesses buildings for their environmental effect and energy efficiency. The program's purpose is to provide a complete framework for analysing new and existing buildings' entire environmental performance in order to promote sustainable building design, construction, and operation. The real estate sectors included by GM's plan include commercial, residential, retail, industrial, hotel, institutional, office, park, and government real estate (Yin et al., 2018).

Building codes and rules for residential and non-residential buildings are generally different. The programme incentivizes developers and design teams to construct green and sustainable structures that save energy, water, and provide a better indoor environment, as well as provide foliage and landscaping for their projects. For existing buildings, GM's scheme promotes building owners and operators to fulfil certain operational objectives and reduce their structures' negative environmental and health impacts on the environment and people over the course of their lives. The following main areas are covered by GM's assessment criteria: energy efficiency, water efficiency, environmental protection, indoor environmental quality and green features and innovation.

1.1.2 Building Construction Waste in Built Environment

The building industry is inextricably linked to the development of the national economy and society. As a result, there is an increasing demand in the construction sector for climate change adaptation and resource efficiency (Ofori et al., 2002), particularly for future prevention and mitigation (Ofori, 1998). While there is a growing awareness of the need for sustainable construction around the world, demand is still low or even non-existent due to a lack of awareness (Shafii et al., 2006).

Moreover, buildings are also one of the primary drivers of world energy use (Cao et al., 2016). In the United States, buildings absorb roughly 48% of total energy (Manic et al., 2016). The building industry consumes roughly 32% of energy in the EU (Ascione et al., 2015). The built environment, in particular, has a considerable impact on a society's ability to deal with climate and sustainability challenges, such as energy consumption (Santamouris et al., 2001), ability to cope with acceptable temperature conditions (Chee et al., 2011), and sustainable building is being used to investigate and address concerns such as emissions and waste, as well as building and renovation consequences (Hammond & Jones, 2008. As a result, there is a constant need to comprehend creative building-scale solutions that might contribute to a more environmentally friendly and resource-conserving metropolis.

1.2 Research Aim

The aim of this research is to study elements of timber prefabricated building systems in order to achieve sustainable planning in Singapore.

1.3 Research Questions

i. What are the current needs of sustainable industrial planning in Singapore ?
ii. How does building construction can minimize waste in built environment and ensure environmental friendly ?
iii. What are the building material needed to enhance the development of timber prefabrication systems in Singapore ?

1.4 Research Objectives

i. To identify aspect of sustainable planning in Singapore to achieve high quality life.
ii. To use timber prefabricated construction as a strategy to contribute minimize waste in built environment.
iii. To introduce mass engineered timber (MET) and required guidelines as a sustainable construction material in Singapore.

1.5 Significance of Research

The purpose of this research is to identify the benefit of using timber prefabrication building systems through a review of relevant literature for urban dwellers in Singapore towards the main issue and challenges in paradigms for sustainable development and enhance living environment. Thus, revealing the impacts and factors of timber prefabricated building construction towards sustainable approach for the built environment. Despite the growing popularity of timber as a structural material in many European countries, it has not been widely adopted in Singapore, as evidenced by the fact that several mass engineered timber (MET) projects completed in Singapore are primarily limited to low-rise buildings with no more than 10 floors.

By going beyond typical methods of introducing MET as an alternate building material option for new constructions in Singapore, the proposal is expected to shed light on the Singapore construction sector. In this way, MET is finally realizing its potential to revolutionize the construction industry by pushing the boundaries of timber construction, and Singapore will be the next country to make a breakthrough with the development of high-rise buildings in timber construction.

1.6 Research Scope

The research of this study focuses on the impact of timber prefabrication building systems toward sustainable planning. The relation between built environment and the three aspects of sustainability, consist of environmental, social and economy will benefit the quality of life. Moreover, timber as a sustainable material will be discussed in detail on the building performance and building guidelines to be referred to in Singapore. Other than that, the research will discuss building system of Mass Engineered Timber (MET) as an approach for enhancing timber prefabrication to help in reducing waste and benefit the environment.

Several case study and literature review timber prefabricated will help to find out several scope and point to highlight in the concept of sustainable planning. The result will be obtained through several case studies for a reference. The research will conclude to a comprehensive scheme for sustainable planning using timber prefabricated architecture.

1.7 Theoretical Framework

Figure 1.2 : The Theoretical Framework

1.8 Research Methodology

The aim of this research is to study on the impact of timber prefabrication building systems toward sustainable planning. Thus, the research methodology acts as a mechanism to recognize the research paradigm and the direction of research. The research gap has been identified as a data collection. The data collection consists of primary and secondary data. The primary data is several case studies on local international projects that use timber prefabrication systems into the design. The secondary data is obtained from articles, journals and reports. All the data have been used to gather data on related topics of timber prefabricated architecture towards sustainable planning. This is important to fulfil the objectives of the research in providing sustainable solutions.

1.9 Summary

This chapter discovers the main issue and problem of the research that has been done on sustainable planning using timber prefabricated architecture, thus, the aim and research objectives are developed in order to respond to the problem statements with applicable literature reviews and case studies. Based on the aim and objectives, the scope of thesis and significance of study are identified as an overview of the thesis result. A series of background studies are explored more in Chapter 2 in accordance with the aim and objective of this thesis.

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