การวิเคราะห์สถานะในกรอบยุทธศาสตร์สำหรับการใช้คอนกรีตสำเร็จรูปอย่างยั่งยืนสำหรับบ้านพักอาศัยราคาประหยัดในประเทศอินโดนีเซีย

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SITUATIONAL ANALYSIS IN STRATEGIC FRAMEWORK
FOR SUSTAINABLE IMPLEMENTATION OF PRECAST CONCRETE FOR
LOW-COST HOUSING IN INDONESIA

Miss Joan Kartini Rossi

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Civil Engineering
Department of Civil Engineering
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Thesis Title	SITUATIONAL ANALYSIS IN STRATEGIC FRAMEWORK FOR SUSTAINABLE IMPLEMENTATION OF PRECAST CONCRETE FOR LOW-COST HOUSING IN INDONESIA
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Field of Study	Civil Engineering
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โจน คาร์ตินี รอสซี : การวิเคราะห์สถานะในกรอบยุทธศาสตร์สำหรับการใช้คอนกรีตสำเร็จรูปอย่างยั่งยืนสำหรับบ้านพักอาศัยราคาประหยัดในประเทศอินโดนีเซีย (SITUATIONAL ANALYSIS IN STRATEGIC FRAMEWORK FOR SUSTAINABLE IMPLEMENTATION OF PRECAST CONCRETE FOR LOW-COST HOUSING IN INDONESIA) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ธนิต ธงทอง, หน้า.

จุดมุ่งหมายของงานวิจัยนี้จัดทำขึ้นเพื่อวิเคราะห์สถานการณ์ของอุตสาหกรรมคอนกรีตหล่อสำเร็จโดยประเมินจากเกณฑ์ความยั่งยืนสำหรับการก่อสร้างบ้านราคาถูกในประเทศอินโดนีเซีย ผู้เกี่ยวข้องที่ถูกสัมภาษณ์ได้แก่รัฐบาลอินโดนีเซียในฐานะเจ้าของงานและผู้ออกนโยบาย ผู้ผลิตคอนกรีตหล่อสำเร็จ ผู้รับเหมา และผู้ควบคุมงานในอุตสาหกรรมการก่อสร้าง วิธีวิเคราะห์เชิงลำดับขั้น (Analytic Hierarchy Process)ได้ถูกใช้เพื่อสนับสนุนการแสดงเชิงปริมาณของการวิเคราะห์ SWOT ในกรอบของ Internal Factor Analysis Summary (IFAS) และ External Factor Analysis Summary (EFAS) สามสิบสามปัจจัยทางยุทธศาสตร์ได้ถูกเรียบเรียงจากห้าเสาหลักของความยั่งยืน ได้แก่ คุณค่าทางเศรษฐกิจ ผลกระทบต่อระบบนิเวศน์ ความเสมอภาคทางสังคม คุณภาพของการทำงาน และการใช้งานและบังคับใช้ ผลการวิเคราะห์แสดงให้เห็นการตอบสนองต่อปัจจัยทางยุทธศาสตร์เหล่านี้ว่าไม่มีความแตกต่างอย่างมีนัยต่อองค์กรผู้เกี่ยวข้องในหลายๆภาคส่วน สำหรับทั้งสามสิบสามปัจจัยทางยุทธศาสตร์ สามปัจจัยสำคัญต่อผู้เกี่ยวข้องในแต่ละภาคส่วนภายใต้แต่ละหมวดหมู่ของ SWOT มีความเหมือนกัน แม้ลำดับความสำคัญจะแตกต่างกัน จุดแข็งยังมีค่ามากกว่าจุดอ่อนสำหรับ IFAS และโอกาสมีค่ามากกว่าอุปสรรคสำหรับ EFAS เมื่ออ้างถึงคะแนนถ่วงน้ำหนักในการคำนวณ IFAS และ EFAS ตำแหน่งของการใช้งานคอนกรีตหล่อสำเร็จสำหรับการก่อสร้างบ้านราคาถูกในประเทศอินโดนีเซียถูกจัดให้อยู่ในจตุภาค “จุดแข็ง-โอกาส” ซึ่งสามารถแสดงได้ถึงโอกาสในการเติบโต ในงานวิจัยนี้ ตัวแปรสำคัญสิบหกปัจจัยได้ถูกพิจารณาว่ามีความสำคัญสำหรับความพยายามในการพัฒนาความยั่งยืนของการใช้งานคอนกรีตหล่อสำเร็จ

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JOAN KARTINI ROSSI: SITUATIONAL ANALYSIS IN STRATEGIC FRAMEWORK FOR SUSTAINABLE IMPLEMENTATION OF PRECAST CONCRETE FOR LOW-COST HOUSING IN INDONESIA. ADVISOR: ASSOC. PROF. TANIT TONGTHONG, Ph.D., pp.

The aim of this research was to conduct situational analysis of industrialized precast concrete by assessing its sustainability criteria to build low-cost housing in Indonesia. The stakeholders interviewed included the Indonesian Government as the owner and donor policy, the precast concrete manufacturers, the contractors and consultants/designers of the construction industries. The Analytical Hierarchy Process AHP hybrid method was used to assist the quantification of SWOT analysis in Internal Factors Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) framework. There were thirty-three strategic factors listed in this research derived from five pillars of sustainability namely economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement. The fact finding revealed that there is no significant difference among various stakeholder organizations in responding the thirty-three strategic factors. The stakeholders also agreed upon the same three-most important factors under each SWOT category; although prioritization among stakeholders is vary. Moreover, the strengths outweighed the weaknesses in the IFAS and the opportunities outweighed the threats in the EFAS. According to the total weighted score calculation of IFAS and EFAS, the position of precast concrete implementation for low-cost housing in Indonesia was located in Strength-Opportunity Quadrant, which implied the possibility of Growth. Finally, sixteen critical factors were considered significant in improving sustainability efforts for precast concrete implementation.

Department:	Civil Engineering	Student's Signature	....
Field of Study:	Civil Engineering	Advisor's Signature	....
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INTRODUCTION

1.1 Background of Research

Indonesia is a country with around 240 million inhabitants. Exponential population growth of the country requires fast physical infrastructure development to fulfil his needs. Among many infrastructures essential to the people, one of them is housing. With high demand and limited land availability, housing construction is a problem intensive industry in which every housing project had different problem characteristics. Improvement on every construction aspect such as management tools, construction methodology, type of material, sophisticated equipment and so on are certainly suggested to solve the problems.

Around mid-1980s the Indonesian government started to seriously promote the construction of low-cost multi-story residential buildings, especially in the big cities. However, not until 2004, when the State Ministry for People's Housing Affairs launched a national movement to construct *one million* low-cost residential units, precast concrete started to gain popularity as an appealing alternative building construction material. Since then, precast concrete has been used intensively (Wijanto and Andriono, 2008).

The use of precast concrete is gaining popular as it offers significant potential advantages. Many kinds of precast products are now used widely in construction industry; such as for buildings, retaining wall, sanitary and storm water, utility structures, water and wastewater construction, transportation and traffic related networks, and marine infrastructures. Precast concrete is preferable as a substitute material, because of its several advantages such as cost-in control environment hence better quality, rapid construction and reduce labor costs. It is appropriate solution for countries which lack of labor and unpredictable weather.

Many researchers have conducted studies to support the use of precast concrete system in Indonesia. The studies mostly focused on structural review since most of large cities in Indonesia are located in medium up to strong earthquake regions (BSN, 2002). In spite of plenty studies leading to supporting conclusion to the use of precast concretes, the number of the businesses are still limited. Consequently, market share of precast concrete is still low.

1.2 Statement of Research Problem

Prefabrication construction method has significant advantages that are commonly cited when corroborating the use of prefabrication (Chen *et al.*, 2010a). It supports the need of rapid housing construction to keep up with the increasing population growth. Government encourages the use of precast concrete due to its advantages to construct low-cost housing, i.e. its good quality and fast construction. In term of quality, buildings that use precast concrete system in Indonesia, particularly flats in Bandung and Pulogebang, survived during 7.3 Richter scale magnitudes earthquake centered in Tasikmalaya on 2009 (Kementerian Pekerjaan Umum, 2010). Meanwhile, the conventional buildings around suffered from significant damage. Moreover, based on Ervianto (2007), the application of precast concrete can save construction time up to 25% and reduce cost up to 24.49% compare to those of conventional method. In addition to the good quality and fast construction, the past researchers also suggested that precast concrete construction has less environmental impact compare to conventional method ((Haas *et al.*, 2000); (Pasquire *et al.*, 2004); (Blismas *et al.*, 2006); (Pan *et al.*, 2007); (Luo, 2008)). Consequently, the application of precast concrete in construction industries should be favourable. In term of economic value, precast concrete should, consequently, enjoy high market demand.

Despite all the advantages and economic opportunities, precast concrete is not popular in Indonesia. Precast concrete manufacturers need to struggle to win orders to balance their huge capital investments (Pan *et al.*, 2007). Even though, 22 precast structural systems have been designed, patented and applied (Nurjaman *et al.*, 2008) and more than 30 precast concrete system were developed (Nurjannah, 2011) in Indonesia, still the use of precast concrete is inferior to other building materials. The restricted road loads for logistics become the issues and higher transportation costs make barrier of precast concrete implementation. The lack in research and innovation to create more sustainable precast implementation is also one factor of slow implementation.

Precast concrete is recognized as supporting construction material for sustainable construction ((VanGeem, 2006); (Jaillon and Poon, 2008); (Shen *et al.*, 2009); (Nurjaman *et al.*, 2011)). Thus, the research direction in decision of using precast concrete is no more about applying such technology or not, but to optimize it. Holton (2009) has conducted research to develop a sector sustainability strategy for the UK precast concrete industry. However, the sustainability issues identification was only based on three bottom line of sustainability: i.e. economic, social and environmental. The latest tool developed by Yunus (2012) motivated the author to improve the identification of strategic factors for precast concrete implementation by considering more comprehensive sustainability issues; namely economic value, ecological performance, social equity and culture, technical quality and implementation and enforcement.

After all, this research was needed to identify strategic factors by considering more comprehensive sustainability issues to assess the current situation and to develop the strategic framework of sustainable implementation of precast concrete in Indonesia.

1.3 Motivation of Research

Strategic framework is a tool to guide future developments. It helps to analyse the internal and external factors that contribute the access to achieve the goal. According to the Bruntland Report (1987), sustainability is to make sure that the development to meet the present needs does not disturb the future generations to meet their own needs. Therefore, many aspects have to be considered not only about environmental impact but also social maturity and the enforcement as well. Yunus (2012) determined five pillars of sustainability; namely economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement.

1.4 Hypothesis of Research

According to the problem statements and motivation, a hypothesis was proposed in this research as follows: “Economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement are the pillars to sustain precast concrete application as promising building materials for low-cost housing in Indonesia."

1.5 Objective of Research

The aim of this research was to conduct situational analysis in strategic framework of industrialized precast concrete by assessing its sustainability criteria to build low-cost housing in Indonesia. To fulfil the aim of the research, the following three research objectives were projected:

- To explore perceptions of various stakeholders of strategic factors in precast concrete implementation. The perceptions include identification of strategic factors, response towards strategic factors and the levels of importance of strategic factors.
- To evaluate the current implementation status of precast concrete in low-cost housing based on identified strategic factors.
- To identify critical factors significant in improving sustainability efforts for precast concrete implementation

1.6 Scope of the Research

In this research, the opinion of several stakeholders; including but not limited to the Indonesian Government as the owner and donor policy, consultants/designers, contractors and manufacturers of precast concrete, toward the implementation of precast concrete for public housing particularly built under the supervision of Ministry of Public Works and Human Settlement was analysed. The type of public housing to be assessed here was low-rise flat housing either for rent (*Rusunawa*) or owned (*Rusunami)*. The type of precast concrete system analysed in this research was specifically referred to precast load bearing wall system. Therefore, the word precast concrete in this report was referred to precast load bearing wall system if it was not stated otherwise.

1.7 Overview of Research Methodology

This research was conducted to develop strategic framework for industrialized precast concrete by assessing sustainability strategic factors relating to precast concrete elements to build low-cost housing in Indonesia based on Yunus (2012) five pillars categories.

The first step of this research was to review literatures about the implementation of precast concrete for low-cost housing. Advantages, barriers and current implementation of precast concrete for low-cost housing were derived from literature review and were confirmed through stakeholders' interview in a preliminary study.

Next, semi-structured stakeholders' interview was conducted to gain the list of SWOT (strengths, weaknesses, opportunities and threats) factors of precast concrete implementation in Indonesia. The result of this step was then used to develop the questionnaire as the main survey tool to meet all the research objectives. The structure of questionnaire was SWOT analysis combined with Analytical Hierarchy process (AHP), i.e. a hybrid method of SWOT-AHP. In this questionnaire, the respondents were asked to make pairwise comparison between two factors in each SWOT categories and to make rating scales for each factor.

The data from the questionnaire were analysed and transformed into a framework of perception map and determined the current situation of precast concrete implementation for each stakeholder.

Finally, the global perception map and current status of precast concrete implementation in Indonesia would, then, be identified. The critical factors that were significant in improving sustainability efforts for precast concrete implementation would be identified as well in this step.

1.8 Expected Outcomes of Research

The main result from this research was situational analysis of the use of precast concrete to build low-cost housing in Indonesia. The research investigated internal (strengths and weaknesses) and external (opportunities and threats) factors of sustainability criteria; namely economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement by integrating the stakeholders (government/owner, contractor, consultant/designer and manufacturer) perspectives. Next, a market position was identified and used as the foundation to build strategy paths (leverage, growth, response, and survival) to make the precast concrete business sustains. Finally, significant critical factors in improving sustainability were identified.

1.9 Outline of the Thesis

This thesis consists of nine chapters. A brief summary of each chapter is provided as follows.

Chapter 1 introduces the rationale of the research. Research background and statement of the problem have been elaborated as the basis of motivation to conduct this research. Hypothesis and objective of the research explain the direction of the research. This chapter also provides an overview to the research methodology and draws a boundary for the research scope. Finally, the expected outcomes of research are designated.

Chapter 2 elucidates the current state of knowledge by reviewing the existing literatures. The areas covered include an overview of precast concrete system characteristics; historical review and current implementation of precast concrete implementation in Indonesia and the method to conduct situational analysis based on sustainability criteria. From the synthesis of this information, the research gaps are described.

Chapter 3 explains the research design to obtain the expected outcomes. Strategic factors of precast concrete implementation are summarized from the literatures and confirmed through semi-structured interview in a preliminary study. The strategic factors identified in the form of SWOT factors are defined. The questionnaire as the main tool in this research is, then, developed. The questionnaire has two objectives: (1) to obtain the stakeholder responses toward the strategic SWOT factors by assigning rating scale and (2) to obtain the stakeholder perceptions toward strategic SWOT factors' level of importance by using pairwise comparison of Analytical Hierarchy Process (AHP). The details of how to analyse the questionnaire results are explained.

Chapter 4 describes the thirty-three strategic SWOT factors developed from the preliminary study as the basis of the main survey tool. The factors are obtained by conducting semi-structured interview of the stakeholders. The opinion of stakeholders of the precast concrete strength, weakness, opportunity and threat (SWOT) are based on five pillars sustainability: economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement.

Chapter 5 discusses the main survey instrument. Survey instrument is a tool to obtain data from respondents in scientific manner. It is important to understand the type and structure of survey instrument to be used in order to provide data analysis easily and achieve survey objective correctly. This research involves questionnaire as the survey instrument. The questionnaire design, questionnaire response and questionnaire validity are discussed thoroughly in this chapter, before taking the next step of analysis of the results.

Chapter 6 discusses the evaluation of the strategic SWOT factors. The evaluation of the factors aims to obtain the stakeholder group perception in responding the strategic SWOT factors by assigning rating scale for each factor. Statistical analysis is used in order to evaluate the data through basic descriptive statistic, reliability of test and agreement on strategic SWOT factors.

Chapter 7 discusses the level of importance of the strategic SWOT factors using the hybrid method of SWOT-AHP, where the opinion from each stakeholder of government, manufacturer, contractor and consultant/designer and the global industry are presented.

Chapter 8 discusses the strategy formulation of precast concrete implementation for low-cost housing in Indonesia. The results of rating scale and importance level of the SWOT factors are multiplied to get the weighted score for each strategic factor. The total weighted score of internal (strength and weakness) and external (opportunity and threat) are then plotted into the SWOT strategic matrix to see the current status of precast concrete implementation in Indonesia. Finally, the critical strategic factors in precast concrete implementation are obtained based on their position on Importance – Response grid.

Chapter 9 summarizes the findings of this research and illustrates the contributions of this research on the improvement of precast concrete implementation in Indonesia. The limitations of the research and recommendations for future research are also provided as guidance.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview of Precast Concrete

2.1.1 Definition

Precast concrete is a construction material produced by casting concrete in a reusable mold or form, which is then cured in a controlled environment, transported to the construction site, and installed into place. Precast concrete is one among many other types of building component that categorized as industrialized construction or prefabrication. Pre-assembly, Modern Method of Construction (MMC), Offsite Manufacturing (OSM), Offsite Production (OSP), Offsite Construction (OSC), and Industrialized Building Systems (IBS) are among the many different terms used to describe industrialized construction and prefabrication of which the terminology provides a rich historical account of the development of the concept. However, regardless of the terms, the idea is the same which refers to manufacture of structure components for the construction of buildings in a controlled environment rather than doing on site (Kamar *et al.*, 2011).

2.1.2 Modular Coordination

Modular coordination is prerequisite for the extensive use of prefabrication (Essiz and Koman, 2006). It is used to coordinate the dimensions of buildings and as a basis to rationalization and industrialization of the building industry. According to Building and Construction Authority (1997) of Singapore, modular coordination is essentially based on:

a. The use of modules (basic module, multi-modules and sub-modules)
b. A reference system to define spaces and zones coordination for building elements and for the components which form them
c. A reference system to rule the location of building elements
d. A reference system to rule the work sizes of building components
e. A reference system to define preferred sizes of building components and dimensions coordination.

CIRIA (1999) cited in (Azhar *et al.*, 2013) defined modular construction as a process of manufacturing, generally conducted at a specialized facility, in which various building materials, prefabricated components and/or equipment are joined to form a component part of the final installation.

2.1.3 Selection of Structural Precast System

According to Building and Construction Authority (1997) of Singapore, the most common precast structural systems are:

"*Frame Systems*

Frame structural systems are suitable for buildings which need a high degree of flexibility. Large spans and open spaces can be achieved without interfering walls. This system is particularly suitable for shopping malls, multi-storey carparks, sports facilities, office buildings and industrial buildings.

Load Bearing Walls and Floors

Precast load bearing walls can appear as walls in shafts and cores, cross-walls and load bearing external walls. Precast wall systems have been used in residential projects. The slabs between walls can either be precast or in-situ flat plat structure. The aim is to build free open spaces between the load bearing walls and to use light partition walls for the internal layout. This offers flexibility in interior layout.

Cells Systems

Cell units are feasible for specific uses of a building, for instance, bathrooms and kitchens. The advantage of the system lies in the speed of construction and high productivity in manufacturing since the finishing and fittings (including mechanical and electrical services) of the cells are completely done at the factory."

2.1.4 Advantages and Disadvantages of Precast Concrete

Precast concrete has generic benefits over concrete construction. Glass (2000) described concrete as material, either it is used as structural or non-structural have numbers of benefits such as fire resistance, thermal performance and sound insulation.

The performance of concrete in fire resistance is better compare to metal and timber, because, a 150 mm thick concrete wall can provide over 90 minutes of fire resistance, which is in excess of most housing required (Glass, 2000). Concrete has normal density that able to contribute usefully to the thermal comfort conditions within a building. The thermal capacity of concrete absorbs and stores heat in the building structure. The heat either re-radiated or ‘purged’ during cooler periods. Concrete offers the possibility of intrinsically solid housing with higher acoustic performance compare to steel or timber systems. The mass law for sound reduction applies for all solid walls, where a doubling of mass improves the Sound Reduction index by 4 dB (Glass, 2000).

The specific benefit of precast concrete over other building materials includes better quality, rapid construction and reduced labor costs. However, the benefits are largely dependent on the design and specification of the buildings (Yunus, 2012). In addition, precast concrete has contribution in sustainable practices by applying integrated design, efficient material usages, and reduction of construction waste, site disturbance and noise (VanGeem, 2006).

Ervianto (2007) found that the use of precast concrete slab could save the cost of approximately 24.49% reduction compared with the conventional method. Precast concrete can be categorized as a green material eligible for sustainable development such as *Reduce, Reuse, Recycle* (Nurjaman *et al.*, 2011). The *reduce* principle applied in material usage efficiency (saving in iron and concrete usage) and work methods. The *reuse* principle applied in repetition use for formwork. The *recycle* principle applied in formwork material that made from recycled material.

In contrast, the main disadvantages to use of precast concrete might include more expensive and longer lead-in times in construction site (Goodier and Gibb, 2007). There is also a need for skilled workers to coordinate the production and installation process. Although the initial investment for the heavy machinery and production system for a precast concrete business involves a substantial amount of money, it is possible to gain costs recovery over the whole life of the precast concrete business. The higher initial cost can be reduced after long-term construction ((Tam *et al.*, 2007); (Chen *et al.*, 2010a)).

2.1.5 Barriers in Implementing Precast Concrete

According to Wijanto (2006), obstacles were found in the use of the precast/pre-stressed concrete system in Indonesia; the system was relatively new and its popularity had not yet reached all regions in Indonesia, there was lack of solemn precast concrete regulation, the capacity of crane in construction work is limited, lack of ample width of road for transporting the precast elements, and also lack of regulation during busy hours for road use. The high initial construction costs when using the precast/pre-stressed concrete system compared with the conventional system has been the main reason for its rather slow development.

2.2 Precast Concrete for Low-Cost Housing in Indonesia

2.2.1 Historical Review and Current Implementation

The applications of precast concrete systems were initiated in 1979 in the construction of *Sarijadi* low-cost medium-rise apartment in Bandung, West Java (Nurjaman *et al.*, 2008). In 1995, *waffle-crete system* (American patent) were used to build *Cengkareng Apartment*, which in turn became the benchmark that motivated Indonesian engineers to design later precast concrete structural systems. *Waffle-crete* system is categorized as a precast *load bearing wall system*. The component of the system consists of floor panels, wall panels and joints. This system is inflexible for modification. *Waffle-crete* panels are designed as a practical span using high concrete quality with light steel reinforcement. The vibrating screed for *waffle-crete* is designed to console the concrete in a single groove. *Waffle-crete* system has been implemented in *Rusunawa* construction in Indonesia since 1995. This system is ideal to work with load bearing wall, floor and wall.

Another precast load bearing wall systems is called *Wasppico.* The system is a heavy solid wall using NMB Splice Sleeve System (dowel + grout) that suitable for jails. Unfortunately, this system is less popular than the other fifty frame systems that are currently in wide use in Indonesia. Other precast load bearing wall systems that have been designed, patented and applied nationwide can be seen in Table 2-1. Examples of building that is constructed by precast load bearing wall system can be seen in Figure 2-1.

Table 2-1.List of precast load bearing wall concrete systems

No	System	Licensed Holder	Year
1	Precast Coupled Wall System	PT Catur Cipta Graha	2011
2	n-Panel System	Puslitbangkim, Public Works Ministry	2009
3	Precon System	PT Dantosan Precon Perkasa	2008
4	Sistem Wall and Slab	PT Griyaton	2006
5	WASPPICO	PT Waskita Karya	2003
6	All Load Bearing Wall	PT Adhimix Precast Indonesia	1998
7	Citra Ratu Bearing Wall	PT Citra Ratu Mulia	1997
8	Waffle Crete	PT Nusacipta Etikapura	1995

(From Nurjaman *et al.*, 2008 and Nurjannah, 2011)

(a) Exterior of waffle-crete system

(b) Interior of waffle-crete system

(c) n-panel system

Figure 2-1.Precast load bearing wall implementation in Indonesia
(source: (a),(b) personal documents 2015; (c) Puslitbang Permukiman, 2010)

In 2007, the stakeholders related to precast industry already developed and test earthquake-resistant precast system to support to “1000 Tower” program for high-rise low-cost owned housing (up to 20 floors) that initiated by the Government (Sidjabat and Hariandja, 2013). Brief explanations of some systems provided by Indonesian Association of Precast and Pre-stress Expert (IAPPI) were presented in Training for Supervisors of Precast Concrete Construction for Building in Jakarta, April 2014.

A comprehensive keyword web search was initiated to gain information of the precast types and volumes in Indonesia. However, it showed that it was difficult to obtain the information about companies who practicing precast concrete. This was related to a number of factors, including:

a. Many companies do not have websites, particularly the small ones.

b. Many companies do not specifically advertise the fact that they make precast concrete items.

c. Contractor plays a role as manufacturer as well, where they set up a temporary manufacturing facility to be used for a particular construction project. This facility will be removed when the project is completed.

2.2.2 Regulation Support

In order to maximize the utilization of precast, the standards of earthquake-resistant instant-low-cost-houses are continuously revised according to the many problems faced by new and existing technology development. Regarding to this, Indonesian National Standard (SNI) of Earthquake-proof Precast Concrete is published by the National Standardization Agency (BSN). SNIs that have been published include SNI 7832:2012 Calculation Procedure for Precast Concrete Work Unit for Building Construction; SNI 7833:2012 Design Procedure for Precast Concrete and Pre-stressed Concrete for Buildings, and SNI 1726:2012 Guideline of Anti-seismic Planning for Building and Non-building Structure. Moreover, other related SNI about concrete structure in general must be considered as well.

According to the Regulation of Ministry of Public Works number 60/PRT/M/1992 on Technical Requirements of High-rise Flat-Housing Constructions Chapter 3 Clause 13, the Flat-Housing must use structure, components and building materials with regard to the principles of modular coordination. The principle of modular coordination already mentioned above is contained in SNI 03-1963-1990. To comprehend this regulation, Regulation of Ministry of Public Works number 05/PRT/M/2007 on Technical Requirements of High Rise Low-Costs Flat-Housing Constructions Chapter 1 for Specific Planning Criteria clearly stated that construction system for high-rise Flat-Housing ought to use precast concrete system. These regulations also support by regulation about personnel to supervise and design for precast concrete. The family tree of law and regulation for precast concrete (Sidjabat and Hariandja, 2013) shows in Figure 2-2.

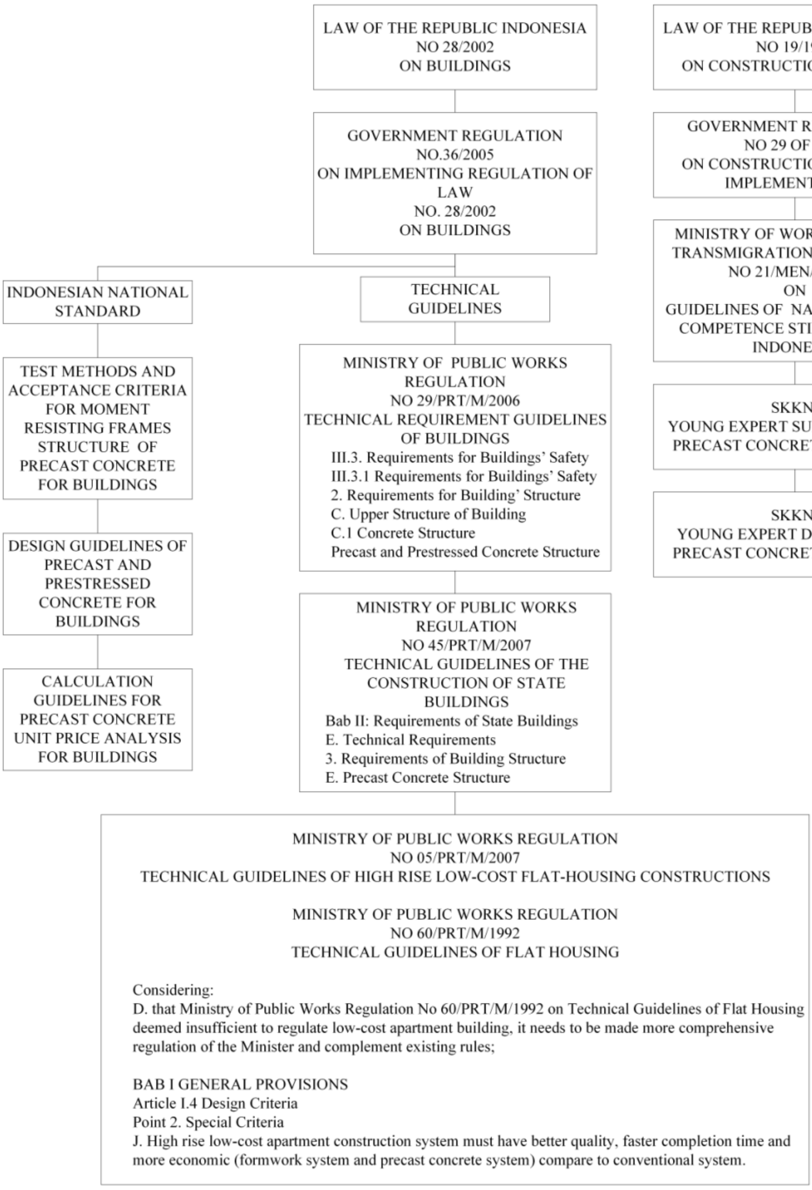


Figure 2-2.Family tree of law and regulation of precast system
(Source: translated from Sidjabat and Hariandja, 2013)

2.3 Sustainability

2.3.1 Sustainable Development

The concept of ‘sustainable development’ usually uses interchangeably with ‘ecologically sustainable’ or ‘environmentally sound development’ (Tolba, 1984). Lele (1991) concluded there are two divergent efforts that should be fulfilled if ‘sustainable development’ is to be really ‘sustained’ as a development paradigm. The first one is making ‘sustainable development’ more precise in its conceptual underpinnings. Meanwhile, the second one is allowing more flexibility and diversity of approaches in developing strategies that might lead to harmonization the living of society with the environment and with itself.

The 1987 World Commission on Environment and Development (WCED) Report, known as Bruntland Report (1987), has defined the term ‘sustainable development’ as a concept in making sure that the development to meet the present needs does not disturb the future generations to meet their own needs. Therefore, this concept addresses the need to include integrating approaches to the current physical development.

Elkington (1997) introduced triple bottom line as the concept of sustainability to be used in the corporate community. The triple bottom line refers to social, economic and environmental. Corporate community increasingly accepted this term worldwide and use it as a framework to making the corporate report (Ding, 2008). For an organization to be sustainable, it must be financially secure, be environmentally friendly, and correspond to societal expectations (Elkington, 1997).

The similar idea comes from Young (1997) who described sustainability as a three-legged stool, with a leg each representing ecosystem, economy and society. The interesting part of this concept that distinguishes it from the triple bottom line concept is that the seat of the stool represents the ‘governance processes’. Young (1997) portrait the three legs as deeply embedded in these governance processes, because it is ‘governance’ which ensures the stability of the system overtime. Therefore, one of stool leg absenteeism will cause instability of the whole stool, because society, the economy, and the ecosystem are intricately linked together (Young, 1997).

Later, Spangenberg (2002a) added the core institutional dimension into the three aforementioned dimensions of sustainability. The core institutional dimension complements the sustainability characteristics of effective compliance such as justice or participation (Spangenberg, 2002a). The four dimensions of sustainability have been defined in Spangenberg (2002b). The social dimension is 'human capital' that consists of human beings intra-personal qualities such as skills, dedication and experiences. The economic dimension includes both formal and informal activities that can improve standard of living beyond the monetary income of the individuals and community. The environmental dimension is the sum of all bio-geological processes and the elements involved in them. Lastly, institutional dimension is the result of interpersonal processes, such as communication and co-operation that results in information and system of rules to govern the interaction of members within society. These dimensions can be characterized by interlinkage indicators that do not refer to one single dimension of sustainable development, but are socio-environmental, institutional-economic and so forth (Spangenberg, 2002a). Therefore, they are easier to understand by looking at the *prism of sustainability.* Figure 2-3 indicates comprehensive structure of dimensions that provides obvious insights into their interaction.

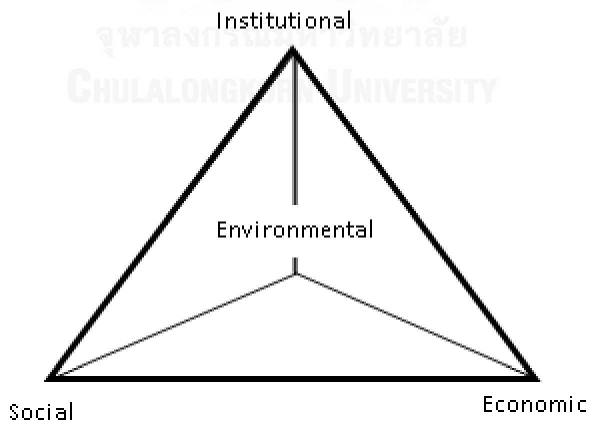


Figure 2-3.The four dimension of sustainability (Spangenberg, 2002)

2.3.2 Sustainable Construction

In 1992, Earth Summit by United Nation in Rio de Janeiro produced a comprehensive plan of action for sustainable development so called Agenda 21. One of the Agenda 21 program promotes sustainable construction industry activities.

According to the Agenda 21, the activities of the construction sector are essential to achieve the national socio-economic development goals in providing residency, infrastructure and job promotion. However, construction work has been accused of causing environmental problems, because of excessive consumption of global resources both in terms of construction and building operation to the pollution of the surrounding environment (Ding, 2008).

The term 'sustainable construction' was originally proposed to describe the responsibility of the construction industry in attaining 'sustainability' (Hill and Bowen, 1997). Kibert (1994) defined 'sustainable construction' as creating a healthy built environment using resource-efficient, ecologically-based principles. Agenda 21 defined sustainable construction as:

"*the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is holistic process aiming to restore and maintain harmony between the natural and built environment, while creating settlements that affirm human dignity and economic equity*" (CIB, 1999).

Similar to the sustainable development, 'sustainable construction' is often associated with environmental impact from construction or building performance in a 'green' way (Ding, 2008). Environmental building assessment methods were developed around the world to reflect the importance of sustainability concept by means of building design and related construction work on site (Ding, 2008). It started since the launch of comprehensive building performance assessment method, Building Research Establishment Environment Assessment Method (BREEAM), in 1990 which was developed in United Kingdom (Ding, 2008). In the United States, Leadership in Energy and Environmental Design (LEED) was developed in 1998 by the US Green Building Council (Crawley and Aho, 1999). Indonesia also has the environmental building assessment methods so called Greenship which is first launched in 2010 (GBCI, 2011). They are only several notable environmental building assessment methods among many others method applied in each country.

The methods provide the information of environment structure, an objective assessment of building performance, and sustainability progress measurement.

However, Ding (2008) argued that the developed methods should not only concern for environmental criteria, but also financial aspect as it is fundamental to all projects. A project may have less negative impacts for environment, but very expensive to build. Ding (2008) added that the single-dimensional approach of environmental is insufficient to evaluate the complex nature of sustainability in buildings. However, because of the term sustainable development is very broad, it may be useful to distinguish between general and specific applications such as ‘sustainable construction’ (Hill and Bowen, 1997), before following the aforementioned principle of sustainable development in the previous section.

The Conseil International du Bâtiment (CIB), an international construction research networking organization, introduced seven Principles of Sustainable Construction in every step of pre-construction, construction and post construction (Kibert, 2012); namely Reduce, Reuse, Recycle, Protect nature, Non-toxics, Economics and Quality.

Hill and Bowen (1997) proposed four pillars of sustainable construction namely: social, economic, biophysical and technical, with a set of over-arching, process-oriented principles. The over-arching process-oriented principles suggest approaches to be followed in evaluating the applicability and importance of each of the four ‘pillars’ of sustainability, and each associated principle, in particular situation. Table 2-2 shows the principles of each sustainability pillars by Hill and Bowen (1997).

Yunus (2012) applied five principles of sustainability to establish the logic and structure in processing critical factors for Industrialized Building System (IBS) in Malaysia. The principles are economic value, ecological performance, social equity and culture, technical quality and implementation and enforcement. He defined these principles by extending the “triple bottom line” to include social, economic, environmental and institutional dimensions. The purport of each of sustainability principles by Yunus (2012) are described in the following paragraph.

Table 2-2.Principles of sustainable construction (Hill and Bowen, 1997)

Social principles of sustainable construction	It includes the improvement of human life quality, a healthy and safe working environment, social self-determination and cultural diversity, skill improvement of disadvantaged people, equitable distribution of the social costs and benefits of construction and intergenerational equity.
Economic principles of sustainable construction	It includes financial affordability for intended beneficiaries, encouragement in employment creation, competitiveness, selection of environmentally responsible suppliers and contractors, and investment in the use of non-renewable resources.
Biophysical principles of sustainable construction	It includes the action of reduce, reuse and recycling of resources such as energy, water, materials and land. It considered the creation of a healthy and non-toxic environment. Less damage to sensitive landscapes, including scenic, cultural, historical, and architectural are also included.
Technical principles of sustainable construction	It includes the construction of durable, reliable, and functional structures. It also considering built environment, using serviceability to promote sustainable construction, humanizing larger buildings, and revitalizing existing urban infrastructure.

Economic value provides attributes that reduce tangible cost and intangible costs for the whole building lifecycle. Ecological performance provides attributes that will increase the ability of IBS construction to conserve natural resources and minimize negative impacts on the environment. Social equity and culture provide attributes that offer long-term opportunities for workers and enhance the quality of life in the local community. Technical quality provides attributes that physically measurable attributes of procedures in IBS construction by meeting professional standards. Implementation and enforcement provides attributes that ensure any planning will be carried out accordingly. Any good planning will be meaningless without proper implementation and enforcement.

2.3.3 Sustainable Construction and Precast Concrete

According to VanGeem (2006), precast concrete could improve sustainability by applying reduce, reuse, recycle principle. It reduces the amount of material used by using industrial wastes such as slag cement, fly ash, and silica fume as the substitute for cement. The formwork of wood or fiberglass can generally be used 40 to 50 times without major maintenance, and concrete pieces from demolished structure can be reused to protect shorelines. The concrete pieces also can be recycled as fill or road base. It also can helps a project earn up to 23 points toward LEED certification for new buildings from a total of 26 points required (VanGeem, 2006). The points are achieved because the sustainable practices contribution of precast concrete by applying integrated design, efficient material usage, and reduction in construction waste, site disturbance, and noise. A properly designed precast concrete system will result in durable building and resistant to natural disasters such as hurricanes, fires, earthquakes, floods, wind, wind-driven rain and moisture damage.

Nurjaman *et al.* (2011) compared environmental impact of conventional construction, half-precast system construction and fully-precast system construction for *Rusunawa* construction. Conventional construction system is construction system that uses conventional technique for structure and architecture. The structural construction is cast in place with timber formwork and architectural wall use plastered bricks or lightweight concrete. Half-precast concrete system is construction system that uses open-frame precast concrete system for the structure and plastered bricks or lightweight concrete for the architectural wall. Fully-precast concrete system is construction system that uses precast concrete system for both the structure and architecture.

Nurjaman *et al.* (2011) used Life Cycle Analysis (LCA) method using SimaPro 5.0 software. SimaPro software is a tool to collect, analyse and monitor the sustainability performance of products and services. It measures the environmental impact of a product and service across all life cycle stages and identifies the hotspots in all aspects of the supply chain, from extraction of raw materials to manufacturing, distribution, use and disposal (www.pre-sustainabilty.com/simapro). The results that show environmental impact from the whole life cycle of conventional construction was 18.6 kPt, while half-precast concrete system and fully-precast concrete system, were 13.0 kPt and 13.8 kPt, respectively (Nurjaman *et al.*, 2011). For the energy consumption, the result for conventional construction, half-precast concrete system and fully-precast concrete system, were 272 kWh/m^2, 175 kWh/m^2, and 219 kWh/m^2 respectively (Nurjaman *et al.*, 2011). Therefore, it can be concluded that construction by precast concrete system is environmentally better than conventional system.

A series of research cycle were conducted by Holton (2009) to develop a sector sustainability strategy for the UK precast concrete industry. The *Best Practice Toolkit* produced by Optimat (Optimat (2002) cited in Holton (2009)) simply provides a framework for managing the strategy development process and identifies a number of techniques that may assist in that process such as SWOT and PEST analyses. Holton (2009) developed a framework for managing the strategy development process by improving Optimat framework as can be seen in Figure 2-4.

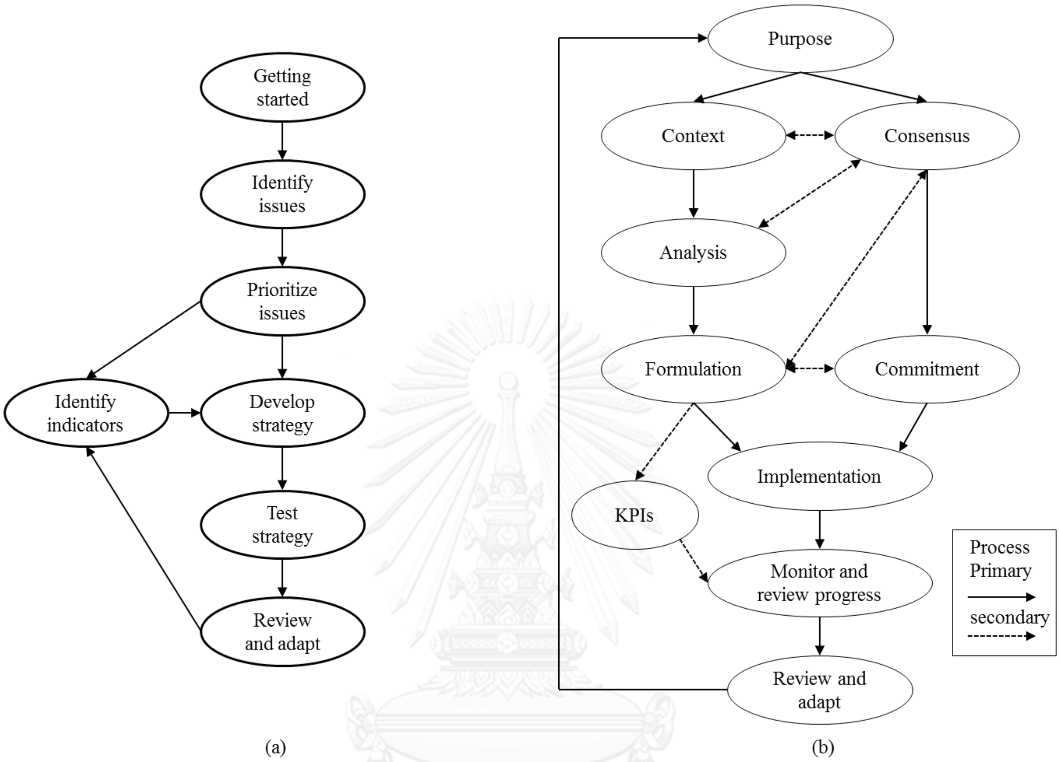


Figure 2-4.Framework for managing the strategy development process
(a) Optimat, (2002), (b) Holton (2009)

Sixteen key issues in the industry's sustainability have been identified by considering economic, social and environmental issues (Holton, 2009). The sustainability issues were:

- Environmental: Energy, Resource use (materials, water, waste), Pollution/emissions, Biodiversity
- Economic: Productivity, Competition, Quality and satisfaction, Profitability, Supply chain interaction
- Social: Health and Safety, Respect for people and their local environment, Employment policies, Contribution to the built environment

- Performance Improvement

These key factors of sustainability were then improved by following action plans to produce long-term plan from improving economic, environmental and social performance in the precast concrete industry. The main elements of the plan were briefly described (Holton *et al.*, 2008) in Table 2-3.

Table 2-3.Action plan to improve precast concrete sustainability performance (Holton et al, 2008)

Key Performance Indicators (KPIs)	A set of indicators to provide an overview of the impact of the precast industry on society and the environment, and how that impact is managed. Companies will also be able to use these indicators to monitor their own performance and benchmark themselves against the rest of the industry.
Sustainability Charter	A set of principles which, if incorporated into the normal business and working practices of a precast company, will encourage it to go beyond legislation and take voluntary actions to make its products and operations more sustainable; It also provides stakeholders in differentiating the companies that are committed to sustainability and continuous improvement of their performance, and those that are not.
Certification Scheme	To provide evidence for independent third-party that the sources from and processes a product has been made is managed in accordance with a series of sustainability requirements.
Best Practice Forum	A series of best practice and other guidance documents will be developed in order to encourage participation and performance improvement across the precast industry. Seminars and workshops held in order to disseminate this information and provide a discussion forum for companies to participate in.
Objective and targets for improvement	These are key feature in any sector sustainability strategy, providing a long-term plan for improving sustainability; they will be developed in consultation with the precast industry and its stakeholders using the KPI data, and be informed by the UK Government's strategies for sustainable development and more sustainable construction.

2.4 Development of Strategic Framework

Construction industry tends to have increasing dynamic situation where changes of technology occur, increasingly stringent regulations and change of client desires as a result of variations in tastes, aspirations and purchasing power (Betts and Ofori, 1992). The industry should be vigilant and keen in clear response to survive. Proper strategic planning is crucial to the success and long-term survival of organization and implementation problems can be traced back to inadequacies in the strategic planning process.

According to *Balanced Scorecard Institute*, strategic planning is the activity of organizational management that is used to strengthen operations, focus energy and resources, ensure the employees and other stakeholders are working toward common goals, set priorities, establish agreement around intended outcomes, and assess and adjust the organization's direction in response to a changing environment. Input for strategic planning includes people, capital, managerial, and technical knowledge and skills (Weihrich, 1982).

There are many different frameworks and methodologies in conducting strategic planning and management. However, similar pattern and common attributes exist, whilst there is no absolute rule of the right framework. According to *Balanced Scorecard Institute*, there are four steps of basic attributes. First is analysis of current internal and external environments. Second is strategy formulation that consists of developing strategy level and recording basic organization level strategic plan. Third is strategy execution by translating the strategy into more operational planning and actions items. The last is evaluation of previously management phase, including evaluation of performance, culture, communications, data reporting, and other strategic management issues.

2.4.1 SWOT Analysis

Among existing approaches and techniques to perform strategic planning, SWOT (strengths, weaknesses, opportunities and threats) analysis is the most common (Hill and Westbrook, 1997). The SWOT approach involves systematic thinking and comprehensive diagnostic of factors relating to a new product, technology, management, or planning (Shrestha *et al.*, 2004). Strength and weaknesses constitute factors within the system that enable and hinder the system from achieving its goal, respectively. Opportunities and threats are considered as exogenous factors that facilitate and limit the system in attaining its goals, respectively. According to Zavadskas *et al.* (2011), SWOT analysis was widely used in economic activities and in formulating strategies for improving and strengthening the national innovations systems, particularly for developing countries. By ensuring a fit between the internal qualities or characteristics (strengths and weaknesses) of a firm and external situation (opportunities and threats) will result a good strategy (Hill and Westbrook, 1997).

According to Weihrich (1982), there were many diverse factors needed to be considered to analyse the external environment. The factors could be grouped into the following categories; economic, social and political, products and technology, demographic, market and competitions factors. Whilst, the internal strengths and weaknesses can be categorized into management and organization, operations, finance and other factors important for a particular organization.

Potential SWOT factors can be gained from drivers and barriers derived in similar studies. The factors were categorized based on the previous literature review to support the five main pillars of sustainability. The categories are economic value, ecological performance, technical quality, social equity and culture, and implementation and enforcement (Yunus, 2012). Table 2-4 provides list of possible SWOT factors extracted from previous research ((Haas *et al.*, 2000); (Pasquire *et al.*, 2004); (Song *et al.*, 2005); (Goodier and Gibb, 2007); (Pan *et al.*, 2007); (Luo, 2008); (Blismas and Wakefield, 2009); (Polat, 2010); (Sadafi *et al.*, 2012); (Lawson *et al.*, 2012); (Yunus, 2012)).

Table 2-4.Potential SWOT factors for precast concrete implementation

Economic Value (EV)	1. Reduce labor cost - *Number of labor is reduced, and so does the living expenses in remote areas* 2. The cost of labor is certain compare with labor in traditional construction 3. Reduce construction time by minimizing duration for production, installation and construction 4. Reduce cost associated with building life cycle (repair, maintenance & operation) 5. Reduce cost of building dismantling and waste treatment operation 6. Reduce cost of production because of repetition, mass and improves quality of the products 7. Precast components more expensive 8. Minimize non construction cost (management, design, tendering) 9. Encourage economic opportunities to local communities by using local resources and offering local employment 10. High initial investment 11. Difficult to achieve economies of scale 12. Increase transportation cost 13. Longer lead in times 14. Speed of return on investment

Ecological Performance (EP)	1. Minimize the amount of energy use during production for components and material used (e.g. aggregates, cements and sand) 2. Promote recyclable or renewable construction contents (e.g. use of fly ash, silica fume, blast-furnace slag and reinforcing steel bar in building construction) 3. Minimize the amount of material used (e.g. natural resources use during design and construction phases) 4. Provide cleaner construction sites 5. Minimize the negative impact of construction activities to the occupants and the local community (e.g. construction noise, dust, light pollution and other pollutions)
Social Equity & Culture (Institute)	1. Minimize the negative impact of traffics to the road users, especially on a congested roadway situation (e.g. transportation of workers, materials, equipment and other items are minimise) 2. Labor productivity is higher than traditional ones. 3. Better workers' health and safety 4. Minimize area usage and staging space on site 5. Encourage infrastructure development 6. Poor detail design of components and connection 7. Lack of expertise & skilled labor 8. Limited public awareness/understanding 9. Increase knowledge to sustainable technologies with available crafts, technical skills or experiences for prefabricated construction 10. Provide job securities for labor
Technical Quality (TQ)	1. Sufficient equipment are unavailable 2. Lack of standardization to simplify transport and installation 3. Provide simplicity in installation and user friendly (e.g. building automatic system, handicap facilities and centralise air conditioning system) 4. Unable to freeze design and specification early 5. Size and load of lifting and transportation 6. Difficulties making changes during on-site work 7. Can survive when disaster occurred (e.g. earthquake, flood and thunderstorm) 8. Construct highly durable buildings, which have a long usable life and cost effective 9. Able to support higher load with a longer span (e.g. beam, column)
Implementation & enforcement (IE)	1. Better quality control results in more success in achieving specifications and less damage of the products before final completion 2. Limited choice of supply chain for project 3. Legislation and qualifications is unclear for precaster 4. Lack of government incentive, directive and promotion 5. Better communication in project because of simple in documentation, clear information and explicit responsibility among stakeholders are provided

However, SWOT analysis is a qualitative approach that depends on capabilities and expertise of participants in the planning process. It does not have analytical approach to determine the importance of factors of assessing the fit between SWOT factors and decision alternatives. In the work of Hill and Westbrook (1997), the shortages of SWOT analysis are:

- The lists can be long
- Prioritization of the identified factors is not required
- Unclear and ambiguous words and phrases
- No conflicts resolution
- No obligation to verify statements and opinions with data or analysis
- Only require single level of analysis
- No logical link with an implementation phase

Several methods to improve SWOT analysis by quantification are available. The methods are discussed further in the next section.

2.4.2 Quantification of SWOT Analysis

2.4.2.1 *IFAS, EFAS and SFAS (Wheelen and Hunger, 2012)*

The Internal Factors Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) plus the Strategic Factors Analysis Summary (SFAS) Matrix have been developed to deal with the criticisms of SWOT analysis (Wheelen and Hunger, 2012). The IFAS and EFAS tables organize the strategic factors of internal (strengths and weaknesses) and external (opportunities and threats) as well as to analyse how well a particular company's management (rating) is responding to these specific factors in light of the perceived importance (weight) of these factors to the company. The rating is continuous rating from 1.0 (poor) to 5.0 (outstanding) based on respondent judgment regarding how well the company is currently dealing with each specific external factor. The weight represents the relative importance of the factor from 1.0 (Most Important) to 0.0 (not important) based on that factor's probable impact on a particular company's current strategic position. All weights must sum to 1.0 regardless of the number of factors. Finally, the rating and weight of each factor are multiplied to get the weighted score. The total weighted score indicates the company performance. The SFAS Matrix then summarizes the strategic factors that required a strategic decision maker to condense the strengths, weaknesses, opportunities and threats by reviewing the highest-weighted EFAS and IFAS factors.

The drawbacks for this method are:

(1) It can only list 8 – 10 factors per table.

(2) The rating scale to assess weakness and threat is confusing, because of negative word. For example to assess the weakness factor of "higher transportation cost", the respondent will be asked "how well you can deal with this factor?" the provided answer will be 1 (poor) if they cannot manage the factor, to 5 (outstanding) if they can manage the factor.

(3) There is no systematic approach in assessing the rating and weight.

(4) There is no systematic approach in determining of what is the most important factor to be considered further in SFAS matrix. These drawbacks later improved by others SWOT quantification method.

2.4.2.2 *IFE and EFE (David, 2011)*

Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) methods are almost similar with IFAS and EFAS table. Both summarize the strategic factors of internal (strengths and weakness) and external (opportunities and threats). In addition, the methods analyse how effective a particular company's management (rating) is responding to these specific factors in light of the perceived importance (weight) of these factors to the company. However, IFE and EFE methods allow users to list factors from 15 to 20 factors per table. The rating is ordinal rating between 1 and 4 to indicate how effectively the company's current strategies respond to the factor. The weight represents the relative importance of the factor from 1.0 (Most Important) to 0.0 (not important) of that factor to being successful in the company's industry. All weights must sum to 1.0 regardless of the number of factors. Finally, the rating and weight of each factor are multiplied to get the weighted score. The total weighted score indicates the company performance.

The drawbacks of these methods are: (1) The rating scale to use in IFE and EFE is different which is confusing. Strengths must receive 3 or 4 rating and weakness must receive 1 or 2 rating, meanwhile opportunities and threats can receive 1, 2, 3 or 4. (2) There is no further approach to formulate strategies.

2.4.2.3 *IFE and EFE (Marimin, 2004)*

Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) of Marimin (2004), are also similar to Wheelen and Hunger (2012) IFAS and EFAS methods. However, Marimin's IFE and EFE provide modification on determining the weight value. The relative importance of weight is determined for each SWOT category. Therefore, the sum of all strengths factor weight must equal to 1, the sum of all weaknesses factor weight must equal to 1, and so on. The total weighted score of internal and external factors can indicate the current status of the company within industry (see Figure 2-6). However, Marimin (2004) did not provide alternative generic strategy to be applied.

2.4.2.4 *SWOT Analytical Method (Chang and Huang, 2006)*

Chang and Huang (2006) developed the quantified SWOT on the basis of the Grand Strategy Matrix (GSM) by Christensen *et al.* (1976). In the GSM, the company is placed in the four quadrants of the coordinate according to their categories (see Figure 2-7). This method is suitable to analyse multiple cases, because it shows the position of a company relative to other companies in a group of analysis. The method gives insight about current status of a company and alternative generic strategies that can be applied. However, this method cannot be used to analyse the single company strategic position.

2.4.2.5 *SWOT Clock Strategic Behaviour (Tirosh, 2010)*

Tirosh (2010) argued that this method provides an answer to the salient drawback of the complexity and difficulty in applying Chang and Huang (2006) method, by simplifying the strategy-shaping process at the small and medium enterprise level. SWOT clock strategic behaviour method provides lists of internal and external Influencing Factor. It has to apply Relative Weight (RW) of the influencing factor, that the total for internal table must equal to 100 and so does the total for external table must equal to 100. The determination of internal strength of weakness and external opportunity and threat is depends on company position towards its Relative Intensity (RI) positioning index. The weighted intensity of an IF is calculated by multiplying the suitable RI and its RW. Finally, Weighted Power Intensity (WPI) is calculated and the current strategic position can be determined.

This method gives insight about current status of a company and alternative generic strategies that can be applied. However, this method only can be used when RI positioning index of a factor is available.

2.4.3 Analytical Hierarchy Process

According to the literature review of several methodologies of quantification SWOT analysis, several shortcomings are noted such as (1) the SWOT factors are measured subjectively, so objective and quantified data is lacking; (2) occurrence of non-uniformity when answering the same question because the SWOT factors' weights are scored subjectively by the evaluation group without a consistency test (Chang and Huang, 2006). To cope with this problem, another decision making tools is needed. Kurttila *et al.* (2000) developed a hybrid method called SWOT-AHP method to improve the quantitative information in determining weight value in Wheelen and Hunger (2012), David (2011) and Marimin (2004) model of internal and external factors evaluation.

Analytical Hierarchy Process (AHP) is a multiple criteria decision-making tool that has been used in almost all the applications related with decision-making (Vaidya and Kumar, 2006). According to Saaty (1980) reciprocal matrix of weights represents the information of pairwise comparison. The assigned relative weight goes into the matrix as an element a_{ij} and reciprocal of the entry ($1/a_{ij}$) goes to the opposite side of the main diagonal that can be seen in the Equation 1.

$$\mathbf{A} = (a_{ij}) = \begin{pmatrix} {w_1}/{w_1} & {w_1}/{w_2} & \cdots & {w_1}/{n} \\ {w_2}/{w_1} & {w_2}/{w_2} & \cdots & {w_2}/{w_n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ {w_n}/{w_1} & {w_n}/{w_2} & \cdots & {w_n}/{w_n} \end{pmatrix}, \tag{1}$$

where row indicate ratios of weights of each factor with respect to all others (Equation 1). In the matrix, when $i = j$, then $a_{ij} = 1$. Vector of priorities or **eigenvector** of the matrix derive by multiply the n elements in each row and take the n^{th} root. The resulting numbers is normalized by divide it by the sum of n^{th} root. The next step is to calculate the maximum or principal eigenvalue (λ_{max}) by multiplying the matrix **A** by

eigenvector to obtain a new vector. Divide the new vector by **eigenvector** and then make the average of the result. The **eigenvector** provides the priority ordering, and the eigenvalue (λ_{max}) is a measure of the consistency of the judgement.

Saaty (1980) demonstrated that $\lambda_{max} = n$ is a necessary and sufficient condition for consistency. Inconsistency may occur when λ_{max} deviates from n due to inconsistent responses in pair-wise comparisons. Therefore, the matrix **A** should be tested for consistency using the formula,

$$C.I = (\lambda_{max} - n)/(n - 1) \quad (2)$$

$$C.R = C.I/R.I \quad (3)$$

where C.I is the consistency index, R.I is random index generated for a random matrix of order n, and C.R is the consistency ratio. A consistency ratio of 0.10 or less is considered acceptable. The consistency index can be improve by homogeneity of factors within each group, smaller number of factors in the group, and better understanding of the decision problem (Saaty, 1993). The following table gives the order of matrix (first row) and the average R.I (second row) that has been determined by colleagues at Oak Ridge National Laboratory (Saaty, 1980).

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

However, according to Ishizaka and Labib (2011), as a decision usually involves several persons, there is adaptation for the standard AHP, so it can be applied in group decisions. The result might be increase inconsistency since several experts are not similar in giving judgments. If a consensus is difficult to achieve (e.g. with a large number of persons or distant persons), a mathematical aggregation can be adopted (Ishizaka and Labib, 2011). One of the method that can be used is geometric mean developed by Crawford and Williams (1985). The approach in minimizing the multiplicative error (Equation 4):

$$a_{ij} = \frac{p_i}{p_j} e_{ij} \quad (4)$$

where a_{ij} is the comparison between object i and j; p_i is the priority of object i; e_{ij} is the error. The multiplicative error is commonly accepted to be log normal distributed (similarly the additive error would be assumed to be normal distributed). The geometric mean (Equation 5) will minimize the sum of these errors (Equation 6).

$$P_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \tag{5}$$

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} \left(\ln(a_{ij}) - \ln\left(\frac{p_i}{p_j}\right) \right)^2 \tag{6}$$

2.4.4 Hybrid Method of SWOT AHP

The SWOT-AHP approach allows the external and internal environments to be scanned and finds important factors (Taleai *et al.*, 2009) influencing the use of precast concrete in a hierarchical structure. To analyse the major factors affecting the use of precast concrete, there are four steps to apply based on Kurttila *et al.* (2000): (1) SWOT analysis, (2) pairwise comparison between SWOT factors within each SWOT group, (3) pairwise comparison between the four SWOT groups, and (4) utilization of the results in strategy development. The combination of a brainstorming session and SWOT analysis with various group of stakeholders makes a useful strategy to rank different factors and identify relevant issues (Mollenhorst and de Boer, 2004) cited in Dwivedi and Alavalapati (2009).

AHP based on pairwise comparisons is sometimes difficult and confusing to the respondents. The participants (decision-makers) have to compare all criteria, two by two, using AHP scales (Taleai *et al.*, 2009). Therefore, Kurttila *et al.* (2000) suggests keeping the number of factors within each SWOT group less than 10 so that the number of pairwise comparisons remains at a manageable level.

Dwivedi and Alavalapati (2009) analysed perceptions of four stakeholder groups regarding forest biomass-based bioenergy development in the southern United States using this hybrid method of SWOT-AHP. As a result, graphic information of each stakeholder was generated. The example of a stakeholder's information is shown in Figure 2-5. Each stakeholder in this research has different perception map of the development. The same result were also generated for stakeholders' perception of the potential silvopasture adoption in south-central Florida (Shrestha *et al.*, 2004).

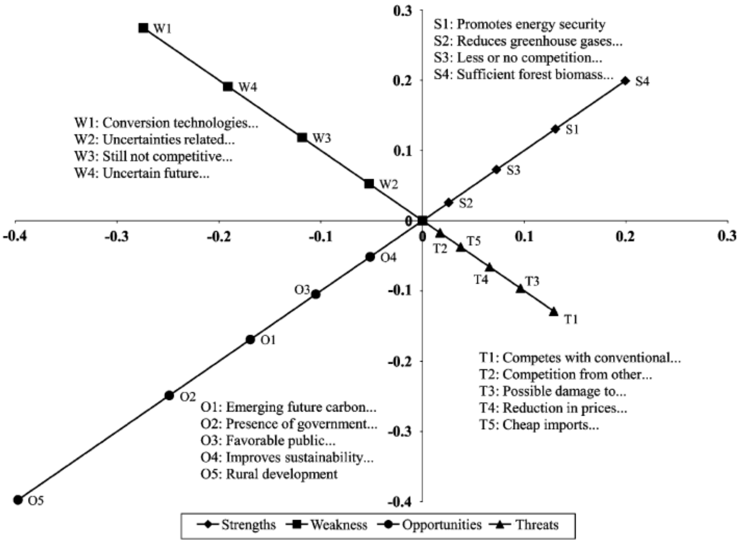


Figure 2-5.Perception map of the NGO stakeholder group for forest biomass-based bioenergy development (Dwivedi and Alavalapati, 2009)

2.4.5 Importance – Performance Analysis Method

Importance – Performance Analysis (IPA) is a technique to measure the attributes of importance and performance to develop marketing programs (Martilla and James, 1977). This method is widely applied in hospitality and tourism, as well as in food services, education, healthcare, banking, public administration and e-business and IT (Azzopardi and Nash, 2013). This method uses Likert Scale to measure the importance and performance of attributes towards a case (Martilla and James, 1977). The attributes are then put into a grid according to their value of importance and performance. The original IPA framework of Martilla and James (1977) is shown in Figure 2-6.

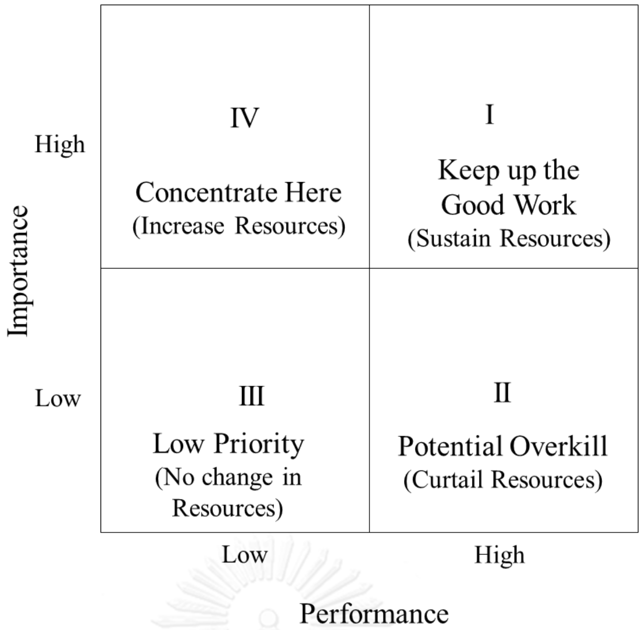


Figure 2-6.The original IPA framework

Source: Marttila and James (1977)

Positioning the IPA coordinate, vertical and horizontal axes (cross-hair) of the grid, is a matter of judgment (Martilla and James, 1977). Data-centred, scale-centred, and diagonal methods are the prevalent approaches to inferring priorities (Azzopardi and Nash, 2013) that illustrated in Figure 2-7. Oh (2001) contended that the scale-centred approach is the better technique because of its transparency in explaining research outcomes. However, when the original scale was truncated, data-centred might be more suitable (Azzopardi and Nash, 2013). Diagonal, in the other hand, is the method to improve the quadrant (data-centred and scale-centred) method shortage in discontinuity in the inferred priority (Bacon, 2003).

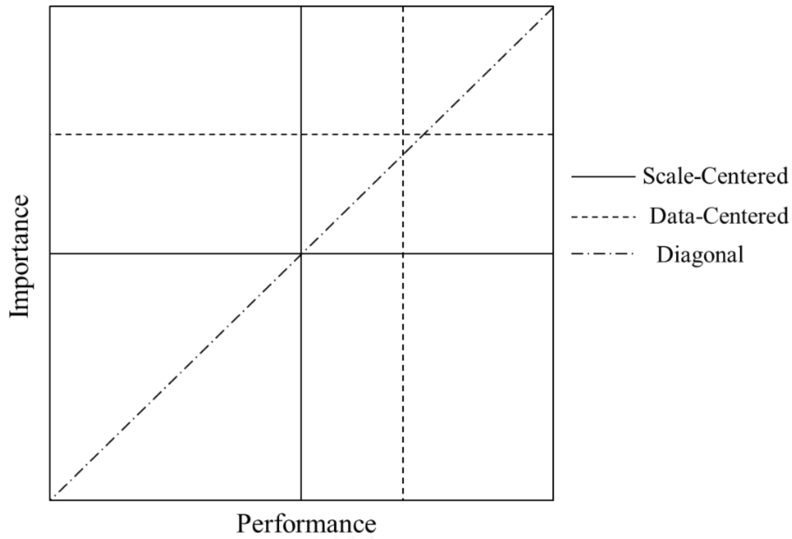


Figure 2-7.The illustration of prevalent approaches of IPA cross-hair
(Source: Azzopardi and Nash, 2013)

2.5 Current Status Identification

The SWOT analysis quantification could reveal the company position in the position and using it as a reference for developing strategies (Chang and Huang, 2006). Several authors have proposed the SWOT quantification and developed their strategy matrix, which are described below.

Marimin (2004) generalized the IFAS and EFAS table to identify the strategic position. The strategic position shows the quadrant location of the company. The quadrant consists of four quadrants that is Quadrant I (Strength – Opportunity), II (Strength – Threat), III (Weakness – Opportunity), and IV (Weakness – Threat). Figure 2-8 shows the positions and the suitable strategy.

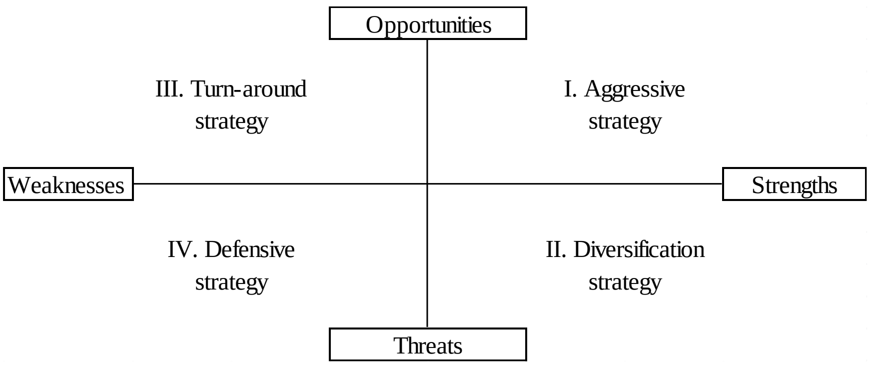


Figure 2-8.Strategic matrix model (Marimin, 2004)

Chang and Huang (2006) developed the quantified SWOT on the basis of the Grand Strategy Matrix (GSM) (Christensen *et al.*, 1976). Just as in the GSM, the company is located in the four quadrants of the coordinate according to their categories (Figure 2-9).

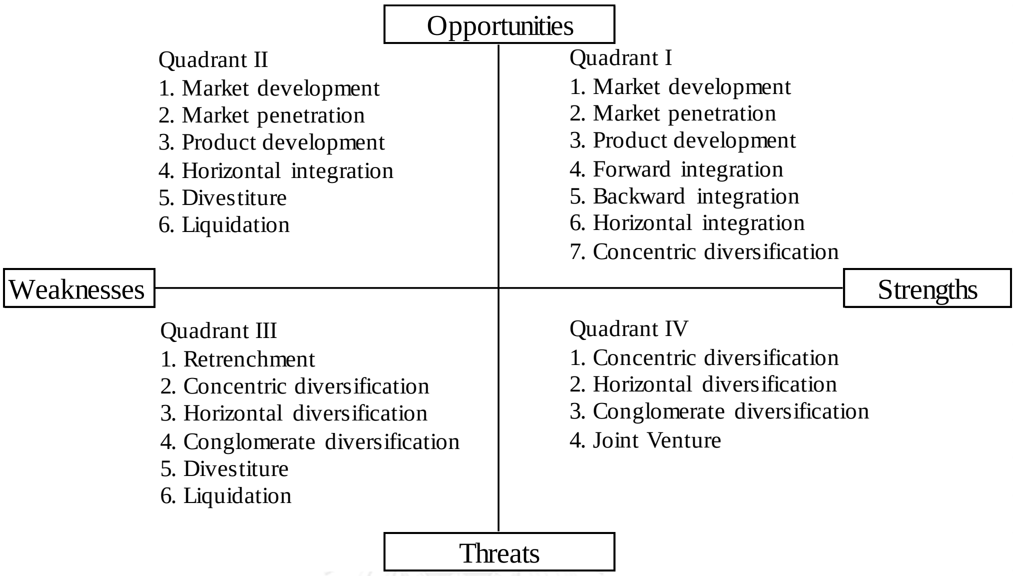


Figure 2-9.Strategic matrix model (Chang and Huang, 2006)

As they noted "*there is a reversal in that the ordinate stands for the external environment (opportunities, threats) while the abscissa stands for the internal environment (strengths, weaknesses). The meaning of the four quadrants is as follows:*

The first quadrant stands for the company's strengths and market opportunities. Company in this quadrant can use their strengths to adopt strategies, such as market penetration, market development, and product development to form competitive strength. If the company in the first quadrant has extra resources, forward, backward and horizontal integration may be efficient strategies.

Company in the second quadrant is those with market developing opportunities but on the weak side of competition. The most urgent issue is to improve their weakness to intensify competitive strength. If tey lack unique competence, they may consider intensifying their competitive strength through joint venture or horizontal merger strategies.

Company in the third quadrant is of low competitive strength and facing threats from other competitors. Defensive strategies, such as focusing on the most favored markets, can be adopted to avoid threats. Divestiture or liquidation should be adopted of these strategies fail.

Company in the fourth quadrant is those who possessing competition strength but facing greater threats than opportunities. Diversification or joint venture strategies should be adopted to reduce threats"

However, Chang and Huang (2006) noted this strategy matrix could only be used if the Quantified SWOT followed the analytical method mentioned in their paper.

The latest Quantified SWOT was introduced by Tirosh (2010) who suggested a *SWOT Strategic Clock* (Figure 2-10) to choose the appropriate strategies regarding the organization positions that can be seen by compare the relation of SWOT clock, Product Life Cycle (PLC) and Boston Consultants Group (BCG), as presented in Figure 2-11.

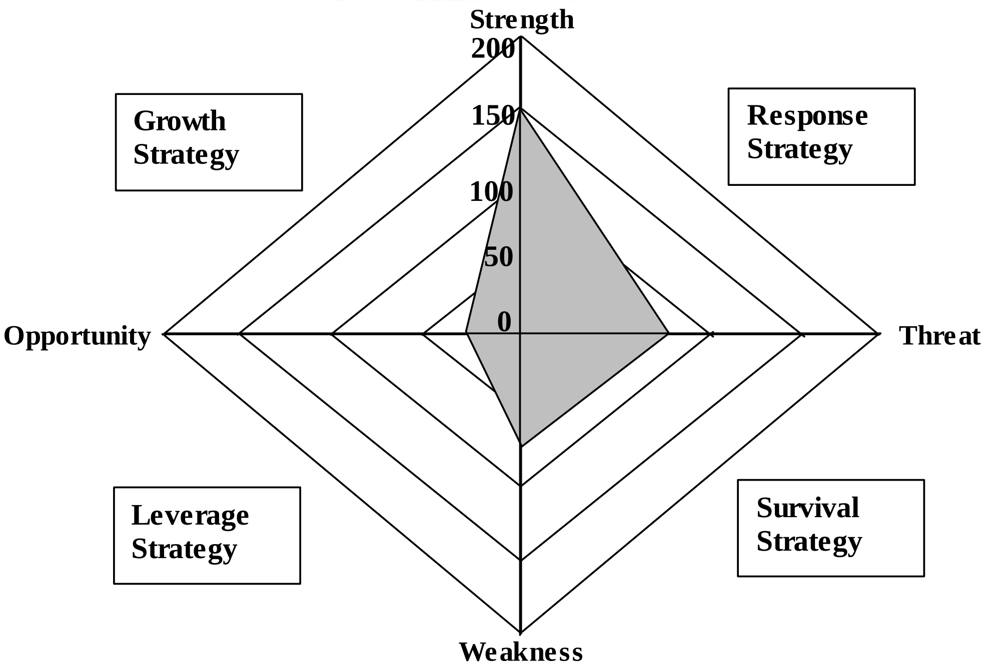


Figure 2-10.The SWOT clock diamond behaviour model

(Source: Tirosh, 2010)

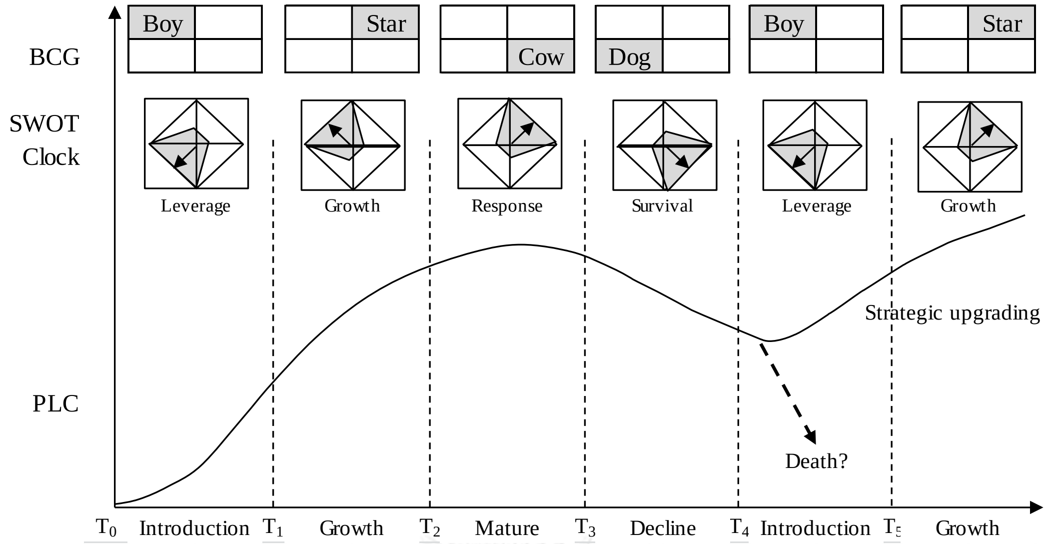


Figure 2-11.Reciprocal positioning of the CLOCK, BCG and PLC models

(Source: Tirosh, 2010)

Tirosh (2010) defined the four generic strategic directions resulting from the simultaneous integration of the Weighted Power Intensity (WPI) of the two external factors (opportunities and threats) with the two internal factors (strengths and weaknesses) as he noted:

"***Leverage (W+O):*** *a situation in which the WPI of opportunities is larger than the WPI of threats and that of weaknesses is larger than that of strengths. The line leads the Leverage strategy. This strategy could be applied in the directions of developing human resources, investments in infrastructure and equipment, developing business units, developing and encouraging innovativeness and creativity, and so on.*

Growth (S+O): *a situation in which the WPI of opportunities is larger than the WPI of threats and that of strengths is larger than that of weaknesses. The Growth strategy involves in a synergic process to grow and expand. This strategy could be applied by market development, product development, vertical/horizontal integration, diversification, market penetration, mergers and acquisitions and so on.*

Response (S+T): *a situation in which the WPI of threats is larger than the power intensity of opportunities and that of strengths is larger than that of weaknesses. Therefore, the Response strategy employs strengths to push the threats* *away. This strategy could be applied and used by cooperation, price war, focusing and differentiating, performance improvement, enhanced HR motivation, and so on.*

Survival (W+T): *a situation in which the WPI of threats is larger than the power intensity of opportunities and that of weaknesses is larger than that of strengths. The Survival strategy reflects the organization's struggle to maintain its continued existence as a living body. In this kind of strategy, action and application modes could include liquidation, dismissals, closing production lines, reducing product basket, limiting number of brands, vertical integration by the buyer, and so on.*"

2.6 Research Gap

Extensive studies have been conducted to assess the perception of using precast concrete system, generally industrialized building system. Furthermore, framework and decision support tools are generated in order to support the extensive use of industrialized building system and help to determine its application and level. PPMOF (Prefabrication, preassembly, modularization and off-site prefabrication) was developed as a decision framework that has variable timing of decision making to assist industry practitioners with evaluating the applicability of *pre-work* on their project (Haas and Fagerlund, 2002). IMMPREST (Interactive Method for Measuring Pre-assembly and Standardisation) toolkit was developed that comprises of two aspects of measurability, identified as hard-soft and simple-complex model to describe classic-cost based methods and undocumented or implicit decisions of choosing traditional or prefabrication alternatives (Pasquire *et al.*, 2004).

Luo (2008) developed a dynamic programming based decision-making and analytical tool namely Prefabrication Strategy Selected Method (PSSM) for prefabrication strategy selection on building system. The goal is to help project teams take full advantage of potential prefabrication opportunities and tactics and determine appropriate strategies across different building systems to better achieve overall project goals. The framework of the construction method selection model (CMSM) by Chen *et al.* (2010b) was developed to assist project members to evaluate construction methods for concrete buildings at early design stages and allowing decision makers to articulate their risk attitudes and uncertainty considerations. The factors identified in these four researches will be used as reference for the proposed research.

In Indonesia, environmentally sound development has been concerned since many years ago. This issue becomes more important since the formation of Green Building Council Indonesia (GBCI) in 2008 (GBCI, 2011). Moreover, BP Konstruksi Indonesia (Indonesian Construction Development Board) strategic planning 2010 – 2014 has task to develop and apply sustainable construction. Therefore, the application of sustainable construction in Indonesia may become mandatory in the future.

Precast concrete is recognized as supporting construction material for sustainable construction ((VanGeem, 2006); (Jaillon and Poon, 2008); (Shen *et al.*, 2009); (Nurjaman *et al.*, 2011)). Thus, the research direction in decision of using precast concrete is no more about applying such technology or not, but to optimize it. Holton (2009) has conducted research to develop a sector sustainability strategy for the UK precast concrete industry. However, the sustainability issues identification is only based on three bottom line of sustainability: economic, social and environmental.

The latest tool developed by Yunus (2012) considered sustainable factors in making decision guidelines for industrialized building system; namely economic value, ecological performance, social equity & culture, technical quality and implementation and enforcement. Eighteen critical factors were identified and categorized into each phase in construction (pre-construction stage, construction stage and post-construction stage). SWOT analysis for each critical factor was conducted to develop strategy of IBS implementation. This research motivated the author to improve the identification of strategic factors for precast concrete implementation by considering more comprehensive sustainability issues namely economic value, ecological performance, social equity & culture, technical quality and implementation and enforcement.

Ervianto (1997) studied the linkages between aspects that should be considered in applying precast concrete system in Indonesia; including material, technology, human resources, production, transportation, erection, connection and structural system. He assessed the economic and engineering feasibility of precast concrete application as structural building elements. This helps the author to refer some economic and engineering factors in sustainability assessment. The factors that influence the use of the modular system in Indonesia are resources shortages (labor, equipment and site), reduce construction time and cost, reduce accident in work and good quality. Meanwhile, according to Khakim *et al.* (2011), the main criteria in concrete works from the most important to the least important are 1) safety, 2) structure reliability, 3) works quality, 4) cost, 5) time, 6) planning, 7) contractor ability, 8) building shape, 9) aesthetic, and 10) weather conditions. The use of precast concrete is superior than conventional concrete in safety, structure reliability, works quality, cost, planning and weather conditions.

Lutfia (2012) assessed factors or activities of value chain and the dominant activities that may effect on increasing competitive advantage in achieving customer satisfaction in Indonesia's precast company. This assessment helps the author to develop another strategy management tool of the success precast concrete implementation.

Research has been done worldwide in decision making area to support the extensive use of precast concrete system. This, nevertheless, does not clearly describe state of the art of precast concrete implementation, particularly in Indonesia. Li *et al* (2014) examined the latest research trend in prefabricated area by analysing published construction management research in 10 leading journals during the period from 2000 to 2013 (as of end of June) in terms of the annual number of related papers, contributions of institutions, adopted data collection and processing methods, and research interest. The finding of the paper resulted in the future direction in industry prospect topic to analyse the SWOT and prefabricated adoption in developing economies.

This research improved the available SWOT quantification tool ((Wheelen and Hunger, 2012); (David, 2011); (Marimin, 2004)) by applying systematic approach of hybrid method of SWOT-AHP of Kurttila *et al.* (2000) to analyse the level of importance (weight), statistical analysis of reliability and agreement among respondent to analyse the response (rating), and Importance-Performance Analysis (Martilla and James, 1977) grid to determine the critical factors. Quantification of

SWOT analysis method by Chang and Huang (2006) and Tirosh (2010) are useful for this research as the basic to formulate generic strategy.

Finally, this research made a significant contribution to the knowledge on industry prospect by conducting SWOT analysis for precast concrete adoption in developing economies of Indonesia. The drawbacks of SWOT analysis were improved with the assistance of systematic approach using statistical analysis and AHP method. The result of SWOT quantification was useful to determine the critical factors and generic strategy formulation for precast concrete implementation in Indonesia.

CHAPTER 3
RESEARCH DESIGN

3.1 Introduction

This chapter provides the research design and methodology adopted in this study. The methodology was designed to satisfy the research objective stated in Chapter 1 using hybrid method SWOT-AHP technique as a tool to analyse the data. This research utilized a combination of quantitative and qualitative research methodologies. In regard to data collection, two methods namely interview and questionnaire survey, were employed. Data were analysed by statistical software SPSS (Statistical Package for the Social Sciences) and Microsoft Office Excel. The results were meant to lead the development of strategic framework of precast concrete for low-cost housing in Indonesia.

3.2 Research Design

The research methodology of this study consisted of four main phases. The phases began with an intensive literature review and preliminary site survey, data collection, and finally analysis and discussion of the results. The data collection and analysis were separated into sections; data collection I and data analysis I, and data collection II and data analysis II. The main approach proposed for data collection I was semi-structured interview, while questionnaire was used for data collection II. The results from analysis I and II led to the SWOT analysis, development of strategy formulation and finding critical factor for precast concrete implementation in Indonesia. Figure 3-1 provides a simplified structure of the research design.

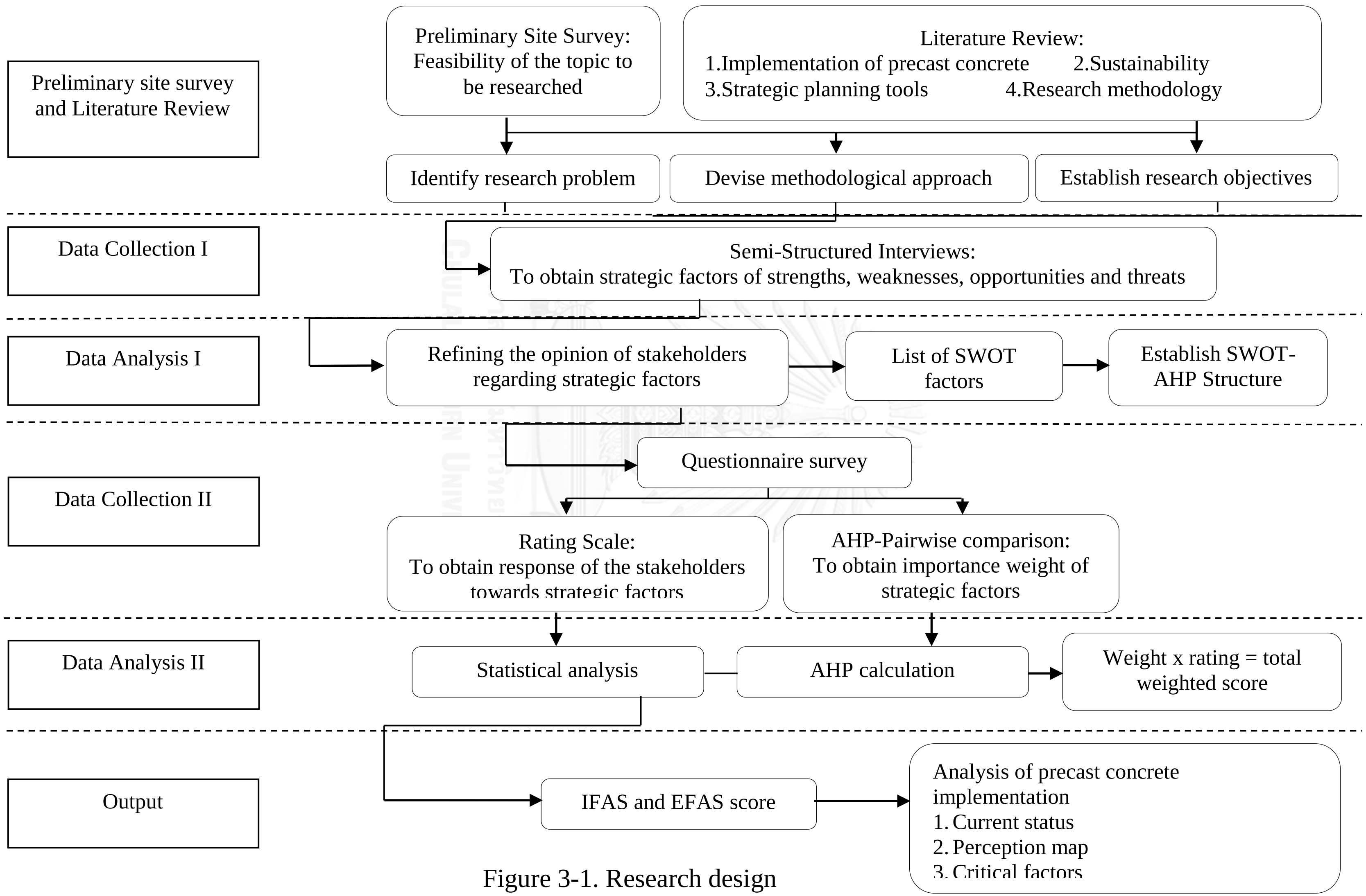


Figure 3-1. Research design

3.3 Research Development

3.3.1 Preliminary Site Survey

Preliminary site survey was needed to look for the feasibility of the topic to be examined. It provided whether the data and information were available or not. It was also important to measure the proper research methodology considering time and cost constraints to achieve research objectives. Thus, the implementation of precast concrete for low-cost housing in Indonesia was selected for this preliminary survey. Interview was conducted by asking open ended question to a manufacturer, a researcher, a consultant and a contractor. Therefore, rough information and problems in the implementation process of precast concrete were identified at the end of this step.

3.3.2 Literature Review

Literature review was conducted to draw the whole picture of precast concrete industry in Indonesia. This step aimed to enrich the knowledge of the researcher with the background of the research project and to provide context ideas. The conference proceedings, journal articles, theses, dissertations, textbooks and related publications were reviewed in this step. The literatures were categorized into 4 groups: (1) implementation of precast concrete, (2) sustainability, (3) strategic planning tools and (4) research methodologies.

3.3.3 Data Collection

Data collection process was developed based on interview and questionnaires survey. Data collection involved precast concrete stakeholders such as Government, Contractor, Manufacturer, and Consultant/Designer. The list of respondents was based on database of Indonesian Association of Precast and Pre-stress Expert, personal contacts, publications, feedback from previously identified stakeholders, and comprehensive internet search.

The first step of data collection was the stakeholders' interview to identify the internal (strengths and weaknesses) factors and external (opportunities and threats) factors that related to precast concrete implementation for low cost housing in Indonesia. Semi-structured interview was conducted. It was well suited to explore the perceptions and opinions of respondents because of the complex and sensitive issues and enable probing form more information and clarification answers (Barriball and While, 1994). The list of possible factors shown in Table 2-3 was used to help the stakeholders determine the SWOT factors while they were also not limited to add some more factors based on their judgments and experiences.

The questionnaire was derived from the interview. There were four sections in this questionnaire, including (1) the information of respondent profile, (2) rating scale of SWOT factors, (3) pairwise comparison of SWOT factors, and (4) open-ended question to further comments and suggestions for the research. In pairwise comparison sections, the respondents have to make pairwise comparison in two levels. In the first level, the respondents measured the SWOT factors from each sustainability criteria. For example, in strength category for economic value criteria, there were *n* factors to be compared pair by pair. The same method was applied for other factors for each sustainability categories. In the second level, the respondents made pairwise comparison for the five sustainability criteria (economic value, ecological performance, social equity and culture, technical quality and implementation and enforcement). The summary of the proposed data collection was tabulated in Table 3-1.

Table 3-1.The summary of the proposed data collection

Data collection		**Content**	**Purpose**
Interview	Section 1:	Information about the respondents' profile	For respondents' profile
	Section 2:	Set of questions to identify strengths, weaknesses, opportunities and threats list regarding to sustainable factors for precast concrete implementation	For research objectives 1, 2 and 3
Questionnaire	Section 1:	Information about the respondents' profile	For respondents' profile
	Section 2:	The rating scale of each SWOT factors using Likert scale	For research objectives 1, 2 and 3
	Section 3:	The pairwise comparison of SWOT for each sustainable factor.	For research objectives 1, 2 and 3
	Section 4:	Open-ended question to further comments and suggestions for the research	For research recommendation

3.3.4 Data Analysis

3.3.4.1 *Statistical Analysis*

There were two kinds of statistical data analysis that applied in this research; namely descriptive statistics and inferential statistics. Descriptive analysis shows modes, median and mean from each variables. Inferential statistic was used to analyse sample data and the result applied to population. Parametric testing and non-parametric testing were included in inferential statistic. However, many assumptions were needed, such as data must be normal distribution for parametric testing, while non-parametric testing is distribution free. Moreover, parametric testing required interval or ratio data, while non-parametric testing required ordinal and nominal data. Since this research is measured by ordinal data, non-parametric testing is used (Table 3-2).

Table 3-2.Statistical analysis for non-parametric testing

Type of Hypothesis					
Descriptive (one sample)	Two sample comparative		Comparative (more than two sample)		Association
	Related	Independent	Related	Independent	
Run test	Sign test	Median test Mann Whitney test Kolmogrov-Smirnov Wald-Woldfowitz	Friedman Two-way Anova	Median extension	Spearman rank correlation
	Wilcoxon matched pairs			Kruskal-Wallis one Anova	Kendall Tau

Source: (Sugiyono, 2011)

Validity and reliability test were used to assess the consistency of respond rate. Validity test was done by looking at *corrected item total correlation* (*r*) in SPSS when significant rate is 0.05. If *r* calculated is positive or *r* calculated more than *r* table, thus the variable is valid. If *r* calculated is negative or *r* calculated less than *r* table, thus, the variable is not valid. Reliability test is used to assess the consistency of measurement tools when repeated measurement is applied. The method was used to assess reliability is *Cronbach's Alpha.*

For the identified SWOT factors, it was also important to consider views and differences between each organization type regarding the relative significance factors in improving sustainability (Yunus, 2012). In this context, the Kruskal-Wallis one-way analysis of variance (ANOVA) was used to assess how these factors were rated by the different types of organization (Wong and Li, 2006). This study did not use matched parametric testing since the variables were measured by ordinal scale and not in normal distribution. The chi-square (x^2) was interpreted as Kruskal-Wallis value and represented the rating distributions in the questionnaire. If the p-value was lower than 0.05, thus differences between the mean ranks of sustainable factors for precast concrete between respondents' organizations exist.

3.3.4.2 SWOT-AHP Analysis

SWOT-AHP was used to obtain the perception from stakeholders and determine the current status of precast concrete in Indonesia. The proposed SWOT-AHP hierarchy is shows in Figure 3-2.

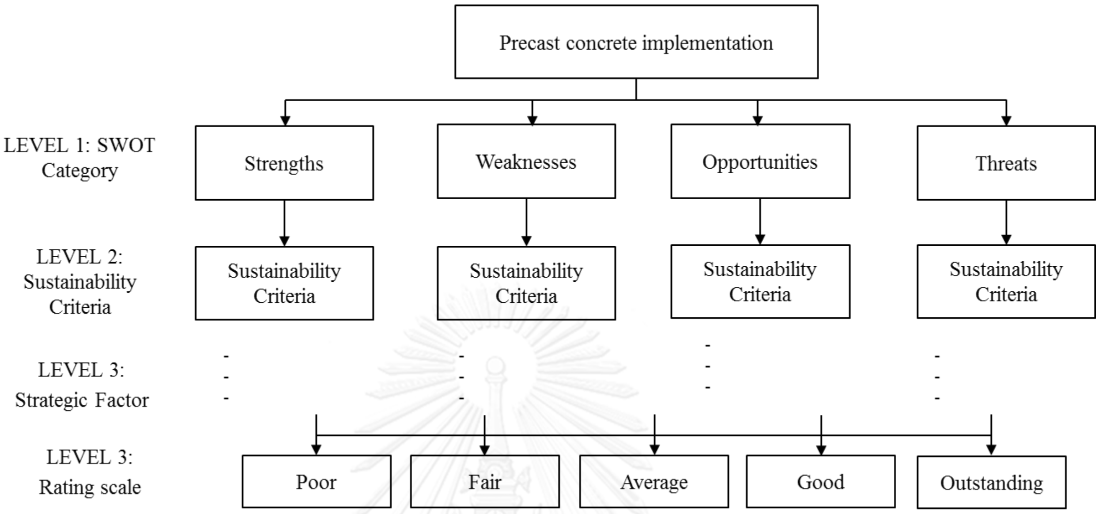


Figure 3-2.The proposed SWOT-AHP research framework

1. Global weight assessment of the SWOT factors for each respondent

The global weight for each factor was determined as the product of its local weight in each level (Equation 7). This process was carried out for each participant in each group of expert. The total global weight score of factors within particular group is equal to one, and each score indicates the relative significance of each factor.

$$\text{Overall significance of strategic factor}_{ij} = (\text{local weight of strategic factor}_{ij})\ (\text{local weight of sustainability criteria}_{j}) \quad (7)$$

Where, j = 1 to 5 (economic value, ecological performance, social equity and culture, technical quality, implementation and enforcement)

2. Global weight assessment of the SWOT factors for each expert group

In the next step, the global weight of the various SWOT factors based on individual experts in each group of stakeholder were aggregated to generate the overall opinion of each expert group. The overall assessment for each group was aggregated using geometric mean method by **Equation (5)**. These scores demonstrated the global opinion of each expert group and offer proper insight for the precast concrete implementation analysis as well as the strategic planning process. This process was carried out for each expert group. In this step, graphical result showing perception map of each group expert was generated.

3. Global weight assessment of the SWOT factors for the global industry

In this step, the overall scores for each expert group were aggregated using **Equation (5)** to produce the global weight of each SWOT factor based on all participants' opinions. The global weight score of factors within particular group of comparison is equal to one and each score indicates the relative global importance of each indicator in the process. In this step, graphical result showing perception map of global industry was generated.

3.3.4.3 Identify Current Status of Precast Concrete Implementation

In this step, Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) were calculated. For example, calculation of the weighted score of strength was described as follows: (i) weight each factor in strength category, the total weights must sum to 1.0, (ii) rate each factor by rating scale 1 (not important) to 5 (important), (iii) multiply each factor's weight with its rating to obtain each factor's weighted score, finally (iv) add the individual weighted scores to obtain the total weighted score for strength category.

The same methodology was used to calculate the total weighted score for weaknesses, opportunities and threats. The IFAS and EFAS can be calculated with equation 8 and equation 9:

$$\text{IFAS} = S - W \tag{8}$$

$$\text{EFAS} = O - T \tag{9}$$

where,

S= total weighted score for strengths category

W= total weighted score for weaknesses category

O= total weighted score for opportunities category

T= total weighted score for threats category

The result of this step shows the market position in which the precast industry located (leverage, growth, response, survival) and the generic strategy be identified as described by Tirosh (2010) in Chapter 2.

3.3.4.4 Determination of Critical Factors for Precast Concrete Implementation

There is no systematic approach in determining critical factors in Wheelen and Hunger (2012) quantification of SWOT analysis method. The critical factors were simply determined by getting the most two or three highest weighted score. Importance-Performance Analysis (IPA) framework by Martilla and James (1977) helped to improve this shortage. The critical factors were then determined when the factors located in quadrant I and IV of more level of importance.

The cross-hair of the grid can be data-centred, scale-centred, or diagonal as explained in Section 2.4.5. The data-centred method is a measure of central tendency of data. There are three commonly methods to measure central tendency of data namely: mean, median, and mode. Mean is an arithmetic average of the data that is calculated by adding all of the scores and dividing by the number of the scores (Adamson and Prion, 2013). Median is the value which occupies the middle position when all the observations are arranged in an ascending/descending order, thus it divides the frequency distribution exactly into two halves (Manikandan, 2011). Mode is defined as the value that occurs most frequently in the data (Manikandan, 2011). The appropriate measurement of central tendency depends on the level of measurement of the data and whether or not the data are normally distributed (Adamson and Prion, 2013).

3.4 Conclusion

This research utilized a combination of qualitative and quantitative research methodologies. Semi-structured interview was applied as a tool in conducting qualitative research to identify the internal (strengths and weaknesses) factors and external (opportunities and threats) factors that related to precast concrete implementation and the results were discussed in Chapter 4. The result from qualitative research is then quantified by distributing questionnaire in the format of rating scale and pairwise comparison to analyse the SWOT factors. The details of questionnaire format and validation were discussed in Chapter 5. The rating scale was applied to measure the stakeholders' response of SWOT factors that discussed in Chapter 6. On the other hand, AHP pairwise comparison was applied to measure the stakeholders' opinion of importance level of SWOT factors that discussed in Chapter 7. Finally, the results of rating scale and importance level of SWOT factors were combined in IFAS and EFAS framework to get the current status, perception map of SWOT factors and critical factors of precast concrete implementation that discussed in Chapter 8.

CHAPTER 4
SWOT FACTORS DEVELOPMENT

4.1 Introduction

Situational analysis is a systematic approach to identify internal aspects and external environment. It is important as a tool to understand the issues in order to generate the possibly strategic path. This chapter describes the identification of the strategic factors of precast concrete implementation in Indonesia. Huge amount of information was needed from intensive literature review and from various stakeholder groups' opinion. This chapter explores situational analysis regarding the pillars to sustain precast concrete application. The pillars are economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement. Each pillar may have its own issues of external opportunities and internal strengths while working around external threats and internal weaknesses (Wheelen and Hunger, 2012).

4.2 Interview Structure and Respondents Selection

The interview was conducted to identify the strengths, weaknesses, opportunities and threats list for precast concrete implementation for low-cost housing in Indonesia. Semi-structured interview type was selected so the researcher can prepare a set of questions that covers the expected interview outcomes during conversation. The interview was delivered through a list of open-ended questions that the respondents can freely express their opinion. The reasons to utilize open-ended questions, as elaborated in Ballou (2008), are: to build rapport and encourage participation, to get factual information, to expand a list, to explain a prior answer, to establish knowledge, to clarify terminology, and to explore new topics. Below is set of questions applied during the interview.

What is the strength of precast load-bearing wall system in term of economic value?
What is the strength of precast load-bearing wall system in term of ecological performance?
What is the strength of precast load-bearing wall system in term of social equity and culture?
What is the strength of precast load-bearing wall system in term of technical quality?

What is the strength of precast load-bearing wall system in term of implementation and enforcement?

What is the weakness of precast load-bearing wall system in term of economic value?

What is the weakness of precast load-bearing wall system in term of ecological performance?

What is the weakness of precast load-bearing wall system in term of social equity and culture?

What is the weakness of precast load-bearing wall system in term of technical quality?

What is the weakness of precast load-bearing wall system in term of implementation and enforcement?

What is the opportunity of precast load-bearing wall system in term of economic value?

What is the opportunity of precast load-bearing wall system in term of ecological performance?

What is the opportunity of precast load-bearing wall system in term of social equity and culture?

What is the opportunity of precast load-bearing wall system in term of technical quality?

What is the opportunity of precast load-bearing wall system in term of implementation and enforcement?

What is the threat of precast load-bearing wall system in term of economic value?

What is the threat of precast load-bearing wall system in term of ecological performance?

What is the threat of precast load-bearing wall system in term of social equity and culture?

What is the threat of precast load-bearing wall system in term of technical quality?

What is the threat of precast load-bearing wall system in term of implementation and enforcement?

Before the interview was conducted, a cover letter containing the researcher background and the aim of the research was given to build trust during the interview. Consent form was also given with the most important point was whether the respondent agree to participate with or without tape-recording. The tape-recording was very useful to allow researcher being focus on questions and later transcript these tapes for analysis. However, some respondents did not agree to participate with tape recording, in this case, carefully jotting notes during interview were applied. The interview document set can be seen in Appendix A.

The respondents represented the stakeholders and consisted of project owners, manufacturers, consultants/designers and contractors who were selected based on their experience in low-cost housing projects, such as the *Rusun Project*, for which precast concrete was used. The owners were the *Rusun* task forces, and the Research and Development of Human Settlement Department, the Ministry of Public and

Human Settlement, the Government of Indonesia. Fourteen respondents agreed to participate in the interviews, which were conducted in July and October 2014.

There were three consultants (CS), two contractors (CT), seven government officials (GV) and two manufacturers (MN) participated in the interviews. Most of them possessed five to ten years of experience. Figure 4-1 shows the distribution of the respondents and their experience.

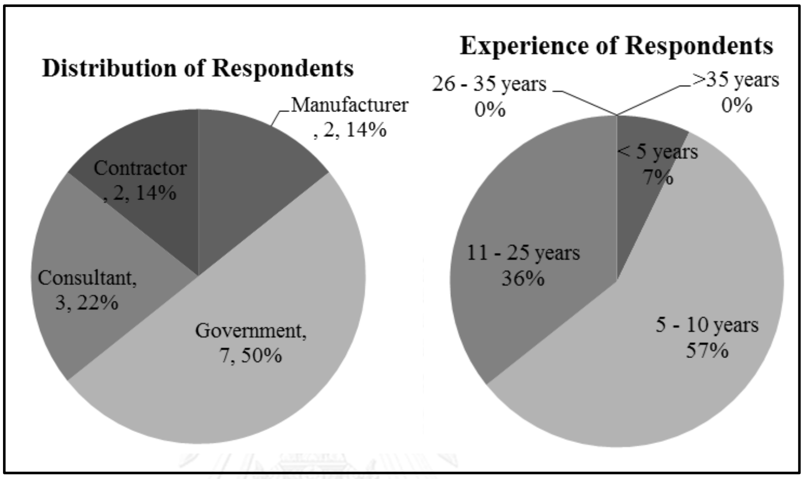


Figure 4-1.Distribution and experience of respondents

4.3 Situational Analysis of Sustainable Criteria

4.3.1 Economic Value

Economic value is the focus in the most prefabrication decision tool model ((Song *et al.*, 2005); (Pasquire *et al.*, 2004); (Luo, 2008); (Chen *et al.*, 2010b)). In term of economic value, precast concrete offers strengths such as smaller on-site area and staging space required, more simplicity in supervision, faster completion time, less scaffolding and formwork, more success in meeting quality specifications, and less labor required. Some of the important remarks in the interview sessions regarding strength economic value are set out in Table 4-1.

All respondents agreed that precast concrete technology could reduce area usage and staging space as most of the production is done in a factory and materials can be delivered to the construction site just-in-time. Such advanced construction technology is needed to overcome the problem of scarce working space in the major cities.

Table 4-1.Remarks made in interview about strength economic value

Remarks	SWOT Factors
CT1: "*The need of space on site is less than conventional.*"	Smaller on-site area and staging space required
CS1: "*Precast methodology is suitable for limited space, since the production can be done at the previous structural floor in rise building.*"	
GV2: "*This factor is very important in the area that has limited space like Java. That is why we use precast.*"	
CT1: "*Precast will makes supervising at the site is easier because the component comes as finished goods, compare to conventional method we will have to supervise all raw material that comes into the site.*"	More simplicity
GV2: "*However, in Kalimantan the project space is big. I think this factor is important since looking for raw material in Kalimantan quite difficult.*"	
CT1: "*The construction time will be faster since the work can be done parallel, you can produce and erect in the same time.*"	Faster completion time
MN1: "*Production can be done at any time and no need to wait the previous floor finish to install. Moreover, bad weather does not affect the undergo production.*"	
MN1: "*The overall construction cost is cheaper since the use of scaffolding is less.*"	Less scaffolding and formwork
CS2: "*Precast methodology is environmentally friendly since it can reduce the use of timber formwork and scaffolding.*"	
CS1: "*In the future, residential construction including structure and architecture expected to be full precast. Currently, the quality of building especially architecture is poor because the labor has poor skill to produce good products. If we just bought a house for 3 to 4 months, then crack defect is emerged, it is very annoying. Meanwhile, precast has good quality.*"	More success in meeting quality specifications
CS2: "*There is risk of not in accordance with specification of cast in-situ. If this is found after installation, dismantling will be difficult. Whereas, specification test of precast can be done before installation, so that the cost of dismantling can be reduced.*"	
GV3: "*Labor requirement at the site is less, but I think they shift labors to work in factory.*"	Less labor required
CS2: "*Precast with automation required less labor, but we cannot apply full automation considering availability of jobs.*"	

The main reason for using precast concrete was to simplify the work required at the construction site. Construction works would be done partially at a factory for the production of precast component. This allowed for fewer trades and interfaces to manage and coordinate on-site (Boyd *et al.*, 2013). It shifts some of the problems of supplying raw material should these are unavailable and/or difficult to find. Therefore, delivering the materials in the form of semi-finished goods reduced the problems that would occur in conventional methods.

Precast concrete systems offered the advantage of faster completion times as a component could be delivered and installed soon after it was produced, while another has begun production. The erection of precast components could be carried out at the same time. Moreover, the production was not affected by weather conditions that usually delay projects, providing a significant solution for Indonesia, which is located in a tropical region and experiences daily rain for half the year.

Precast bearing wall systems consisted of combinations of walls and floor structures. Half-slab, instead of full-slab, precast concrete was selected for the monolithic structure between walls and slabs in floor structures. Half-slab also served as formwork, similar to wood formwork which can only be used once in traditional construction, thus reducing the cost and wood usage of formwork. A case study conducted by Ervianto (2007), of a classroom building in Yogyakarta, found that using half-slab had reduced the cost of the formwork and scaffolding by around 24.49% more than using the traditional method.

The advantage of precast concrete was the guaranteed quality, of its stages of production from the raw materials to the finished-goods, because the quality of the ready mix could be more easily maintained under factory conditions. The quality of a component was usually checked before installation, and if the quality did not meet specifications, the component was rejected. Defects and damages were also easier to detect, and repairs were easier to make, unlike in traditional construction where components were checked after-installation, incurring additional costs should uninstalling be required.

Less labor was required at the site of construction as precasting components was carried out in a factory, where semi-automated or fully-automated machine processes resulted in higher productivity. At the construction site, labor was needed only to install the components. This also reduced both construction time and on-site labor wages.

However there were also weaknesses such as repetitious designs, higher transportation costs, licensing fees, higher initial investments, heavy equipment dependent. Some of the important remarks in the interview sessions regarding weakness economic value were set out in Table 4.2.

Repetitious designs are a key characteristic of mass production. Despite the increasing need for housing every year, the *Rusun* project was still limited. A cheap housing project generated only a small profit margin such that very few private companies showed interest in precast construction. Only the government obliged to build such projects for low-income citizens, but the government has limited funds, therefore backlogs in the provision of housing could not be avoided. The limited number of projects only provided limited opportunities for contractors to bid, hence there was little incentive to make a huge investment to build a precast factory. However, this factor can be considered as strength in some circumstances. It would be an advantage if many projects were to use the same formwork design. The suggested number of repetitious designs was 100 elements in order to ensure cost-effectiveness of a project (CPCI, HDB, 2014).

The cost of transportation depended on the distance from the factory to the construction site and on the obstacles that might be encountered along the delivery routes. Sometimes it required more methods of transportation and handling that added additional work. For example, the capacity of bridge on the delivery route was not sufficient, so then the contractor should build a new bridge. Another example was to deal with overhead obstruction such as cable electricity.

Licensing fees are paid to develop a precast concrete system or to purchase a license to use an existing precast concrete system. When a Contractor (A) won the project and wanted to use another system (Contractor B), he usually hired Contractor B as a subcontractor for structural work. The fee to use another system was around 2.5% to 3% of the cost of total project. However, the supervision of copyright usage was not stringent. Many problems such as inadequate ability of the contractor can emerge. As a result, the precast components could be of bad quality and delay the construction project.

Table 4-2.Remarks made in interview about weakness economic value

Remarks	**SWOT Factors**
GV1: "*There was a contractor-precaster who gets several projects with typical design. Therefore it produced the precast in factory with the same moulds and equipment.*"	Repetitious designs
GV5: "*Precast technology should enjoy economical profit, since mould can be used several times. However, the number of project is limited since the awareness of owner/developer still has limited knowledge about this, therefore economy of scale is difficult to achieve.*"	
GV7 "*I do not agree this factor considered as weakness. Since the design of Rusunawa is typical and not need much complex architecture. I think precast technology is very suitable for Rusunawa.*	
CS1: "*Precast made in factory maybe have better quality, but the transportation cost will be high, depend on the distance from factory to project site*"	Higher transportation costs
CS2: "*From the transportation side, there is road limitation where long and big component is difficult to transport. This makes price for precast made in factory more expensive.*"	
CT2: "*Precast that has been produced in factory has weakness in mobilization that related to cost. Moreover the handling during delivery must be careful to avoid reject at the site.*"	
GV1: "*Precast concrete system only owned by several contractors. If a contractor does not have a license, it must collaborate with the one who has the patent. Their bid price will be higher than contractor-precaster since there is copyright fees. Moreover, it is found that the contractor only pays the fee but does not get adequate training and supervising to erect the precast, hence delay will be happened.*"	Licensing fees
CT2: "*The initial cost to implement precast is high because we have to provide heavy equipment, set up the factory and so on. However, if the construction is faster, the cost from operational will be reduced and at the end the cost will be less than conventional method.*"	Higher initial investments
CT1: "*Construction with precast is heavy equipment dependent. However this heavy equipment is expensive. This makes overall construction cost of precast is the same with conventional since despite several items are cheaper but on the other side some items are expensive, like heavy equipment so it increases the construction cost.*"	Heavy equipment dependent
MN1: "*The heavy equipment is expensive.*"	
CT2: "*The weakness of precast methodology is heavy equipment dependent, because the panel cannot be lifted by person.*	

Substantial initial capital is needed to build a factory. A large enough area, high technology automation machinery, sufficient equipment, and sufficiently skilled workers are all as well. The capital owner must be convinced of a good return on investment, and projects capital returned by the precast bearing wall system will be sustained.

Adequate space is needed to allow heavy equipment to manoeuvre. Site access and space to manoeuvre, and the availability of and access to construction crane affect the construction time. This is the main concern, since precasting requires heavy equipment for production and installation.

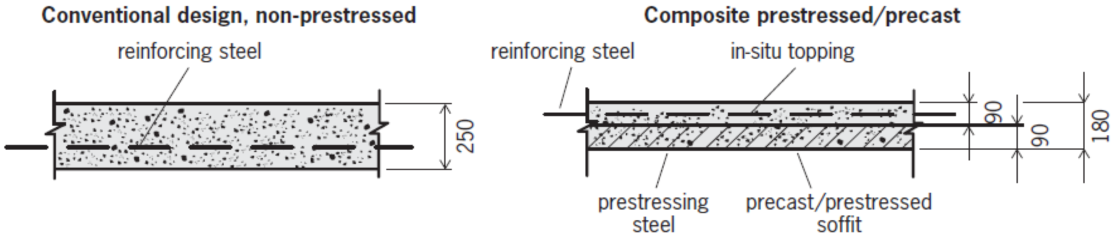
4.3.2 Ecological Performance

Ecological performance is the ability of precast concrete technology to be environmentally friendly. Precast concrete technology is able to have good performance for environment such as more efficient material usage and cleaner construction sites. Some of the important remarks in the interview sessions regarding ecological performance are set out in Table 4-3.

Table 4-3.Remarks made in interview about ecological performance

Remarks	SWOT Factors
CS1: "*Compare to open-frame system, precast bearing wall spends a lot of concrete material since the panel thickness follows the design of seismic requirement. However, the use of other materials such as bricks is zero and less formwork and scaffolding since the formwork can be used many times.*"	More efficient in material usage
CT2: "*Precast construction can be localized the debris compare to conventional, so it provides cleaner construction site*."	Cleaner construction sites

Adopting precast concrete requires less construction material, including the raw materials for concrete (cement, sand, aggregate and concrete), and timber for temporary formwork and scaffolding, resulting in overall savings, have a significantly positive impact on the environment. All materials can be carefully managed and waste can be recycled. According to Yee (2001), in the case of a conventional in-situ floor slab design, considerable savings in materials can be realized when a composite pre-stressed and precast slab system is used. For example, when pre-stressed/precast construction is applied to a slab system spanning 8 m and designed to support a live load of 4 kPa, a savings of 28% in concrete and 45% in steel materials can be realized (Figure 4-2).



Material	Conventional design, non-prestressed	Prestressed/ Precast	Material savings
Concrete	0.25 m^3/m^2	0.18 m^3/m^2	28%
Reinforcing steel	18.30 kg/m^2	6.20 kg/m^2	45%
Prestressing steel	-	3.85 kg/m^2	45%

Figure 4-2.Flat slabs (one-way span). Design for live load 4 kPa. Clear span = 8 m.
Source: Yee (2001)

According to Nurjaman *et al.* (2011), for the *Rusunawa* project, full precast systems, as opposed to semi-precast system and conventional methods, required less material for making concrete and eliminated the use of timber in formwork and scaffolding by using steel instead (Table 4-4). Steel formwork and scaffolding last longer than timber does, require less labor and construction time, and offer more competitive costs.

In the conventional method, all the raw materials, such as cement, aggregates, sand, bricks, and timber formworks, are transported to the construction site, which becomes crowded and dusty. Most of the time, the quality of in-situ cast concrete does not in accordance with dimension specifications due to formwork that have been poorly set-up, allowing the concrete to leak out from the sides, or formwork that are sagging from inadequate shoring. This requires the concrete to be reformed by cutting it for a good finishing, but results in more debris at the construction site. Precast concrete production, with factory-made components delivered to the site as semi-finished goods, would not require such finishing work. The dimensions of the components are all synchronized without needing any further chipping or cutting, and without excess debris.

Table 4-4.Material comparison of conventional and precast construction

No	Material	Conventional	Semi-precast	Full-precast
1	Cement	488 ton	499 ton	617 ton
2	Sand	3,483 m^3	3,354 m^3	687 m^3
3	Aggregate	339 m^3	398 m^3	642 m^3
4	Reinforcement	180 ton	77 ton	122 ton
5	Formwork	Timber 41 m^3	Steel 7.9 ton	Steel 9.2 ton
6	Scaffolding	Timber 562 m^3	Steel 7.8 ton	Steel 7.8 ton
7	Red Bricks	413,216 pieces	413,216 pieces	-
8	Skilled labor (people)	20	30	40
9	Unskilled labor (people)	80	45	15
10	Cost (Rupiah in Billion)	13.657	11.500	11.434
11	Building height/ floor area	4 story/4,600 m^2	4 story/4,600 m^2	4 story/4,600 m^2
12	Construction time(month)	8	6	5

Source: Nurjaman, *et al* (2011)

4.3.3 Social Equity and Culture

Social equity and culture is vital in sustaining the community welfare where Industrialized Building System (IBS) construction is to be operated (Yunus, 2012). Precast concrete system offers positive impact of job securities. However, it faces more threats such as traditional foreman-handyman culture, limited public awareness, centralized development in Java Island and limited expertise and skilled labor. Some of the important remarks in the interview sessions regarding social equity and culture are set out in Table 4-5.

The foreman-handyman culture in traditional construction business is different from that in prefabricated construction one. Indonesian businesses require labor intensive work, which is suitable to the situation of traditional construction. Therefore, even though the advantages of precast concrete systems are well known, there is lack of desire for implementing these systems, as the traditional system is seen to provide more jobs. Moreover, substantial training and funding are required for workers to be able to move from working in traditional construction projects to precast projects.

Table 4-5.Remarks made in interview about social equity and culture

Remarks	SWOT Factors
MN1: "*Precast concrete implementation supports professionalism for labor and can minimize the need of outsourcing.*"	Greater job security
CS1: "*There is habitual factor that the contractor does not want implementing precast concrete, even the economic advantage of precast has been presented. They afraid that their people will lose their job or they still doubt about the technology.*"	Foreman-handyman culture difficult to change
CS2: "*Contractor will prefer to work with conventional method since the scheme is more familiar, whereas quality supervision for precast methodology is better.*"	
CT2: "*Socialization must be more intensive because many stakeholders especially developers do not understand about precast technology. They think precast is not monolith because precast is installed element per element, unlike conventional method.*"	Limited public awareness
GV1: "*Indonesia is huge, I think the only developed region in term of resources like equipment, expert, and material, to implement precast concrete is Java Island. The precasters only grow in Java island. Whereas, many projects placed outside Java and these will be difficult if the contractor does not have license.*"	Development centralized in Java Island
CS1: "*Most of consultants and designers in Indonesia have limited knowledge in precast concrete system. The designer has less vision in adopting precast concrete. Many precasters come from contractor, and unfortunately they rarely foster the company system and the workforce gradually. Therefore their development are stagnant*"	Shortage of expertise and skilled labor
GV1: "*However the workforce is lack of skill in erecting precast concrete system and it takes time to train the workforce.*"	
CT2: "*It takes time to train the labors if they are not used to precast construction.*"	

Precast concrete systems have been used widely in government projects all over Indonesia. However, there has been bad publicity regarding leakages at the connections, and no shortening of construction times as compared to traditional systems. Moreover, substantial initial capital is needed when a precast concrete system is wanted for a project. These negative factors have hindered all the advantages of the technology and have made stakeholders unenthusiastic to adopt it. Most private projects still use conventional methods for precast structures due to limited knowledge of the engineers and the lack of socialization.

Most of the skilled workers in pre-casting are on Java Island. Therefore, for any projects outside of Java, there are costs incurred to transport personnel. Some regions have inadequate equipment and materials, which also incur costs and require much time to deliver construction project.

Indonesia might have a large workforce, but a small portion of it possesses adequate skills in pre-casting, thus any skilled personnel is likely to experience overload work. Many projects share the same experts. Sometimes a project has to wait to be executed due to the expertise and labor being occupied with another project.

Despite of external threat mentioned above, precast concrete offers job security to the labor. Traditional construction work tends to be seasonal. Consequently, the level of the skills of construction workers tends not to be professional as the workers are not continuously engaged in construction work. Moreover, there is less job security as jobs are only seasonally available. Since the precast concrete production phase is performed in a factory, a portion of construction workers will be employed there where working conditions are better and work contract engagements are more certain.

4.3.4 Technical Quality

Technical quality is important to be evaluated in accommodating structural and architectural requirements. It helps to identify both the narrow and broad impacts of precast concrete system in improving sustainable deliverables (Yunus, 2012).

The strengths of precast concrete system are more highly durable buildings and compensation of earthquake reduction factor. Some of the important remarks in the interview sessions regarding strength technical quality are set out in Table 4-6.

Although there is scepticism about the capacity of precast load bearing wall to resists earthquake in Indonesia, there have been numerous reports that the capacity is actually higher (Raths, 1974, Hirosawa *et al.*, 1988, Sekulovic *et al.*, 1996, Freedman, 1999). A notable advantage of precast construction is in the inherent ease of defining load paths through connections (Freedman, 1999). Precast load bearing wall systems should be designed not only for the joint of components, but also for whole building systems. Further design considerations are beyond the scope of this report.

Table 4-6.Remarks made in interview about strength technical quality

Remarks	SWOT Factors
MN1: "*Precast concrete has durable characteristic either during construction and maintenance. The quality is good since the production under monitored environment and it is not easy to deteriorate during maintenance period.*"	more highly durable buildings
GV6: "*As my experience in designing precast bearing wall can act like monolith structure because the slab is half-slab and it will be topping again, hence the connection between slab and wall is monolith. At that time the standard is not as high as today, but it still can fulfill the specification.*"	compensation of earthquake reduction factor

Precast concrete has weakness in its complex connection design. Indonesia is located in seismic region, thus the requirement for connection designs is very stringent. The joints, which function to transfer loads, must be capable of joining each precast concrete component into a continuous monolith (Wijanto, 2006). The innovations for the joint systems are emerged and patented. Not every contractor has their own precast concrete system patent. Therefore, the expertise is limited only to the manufacturer/contractor who owns the system. If another contractor wants to apply the product, it would lead to longer times of construction, because the contractor has to apply for the license. Moreover, the contractor may not have experience working with the system, hence requiring extra time for learning. Complex connection design is the main technological problem that requires stringent supervision for installation and quality control. If the engineer fails to supervise correctly, water leakage along the joint is prone to occur. There are many cases of water leakage in *Rusunawa* as a result of poor supervision during installation. This contributes to bad publicity for precast concrete structures.

Another weakness for precast concrete is loading difficulties of big component and long span. The precast components should have minimum double handling by stored with careful consideration of the erection sequence (BCA, 2010). Double handling has to be avoided since the components have not yet gained their full designed strength, so they are generally more susceptible to damage during handling. It is important to keep them handled consistently with their shapes and sizes to avoid excessive stress or damage. Moreover, the installation of precast components is acknowledged to be a potentially high risk activity since it involves the use of heavy plants, cranes and personnel working at great heights. Therefore, the designer must pay attention to the on-site practices of handling precast units and their installation sequences at the design stage (Precast Flooring Federation, 2013).

Precast concrete also has limitation in making changes during construction. Precast concrete systems used in a project usually belong to the contractor; hence changing contractors is not an option when there is a dispute. It takes time to train a new contractor to install a different precast concrete system. The detailed engineering design of *Rusunawa* was altered several times. The alteration of design affects the formwork and production cost. This led to delays in construction. Some of the important remarks in the interview sessions regarding weakness technical quality are set out in Table 4-7.

Table 4-7.Remarks made in interview about weakness technical quality

Remarks	**SWOT Factors**
CT1: "*Supervising for installation must be stringent, since precast technology lied on the joint. It is dangerous if the supervision is not done by the expert.*"	More complex connection designs
MN1: "*There is problem at the joint. It is prone to have leakage if not supervised correctly.*"	
CS2: "*User used to complain about leakage. It might be happened because of lack of supervision when joint installation.*"	
CT2: "*The supervision on joint installation must be strict because if it is not, the joint will be poor and will be damaged if there is earthquake and so on.*"	
CT2: "*For big component or long span must consider design for handling. More attention when lift the component for installation to avoid twisting.*"	Loading difficulties for big components and long spans
GV4: "*In a conventional method, when there is dispute in the project, we can change the contractor. However, it is difficult to do the same thing in precast construction, because changing contractor will effects the used of precast system.*"	Greater difficulties in making changes during construction
CT2: "*Detailed Engineering Design of Rusunawa usually changes all the times during construction. It will affect the type of formwork and production cost. This is one of the causes of delay in project.*"	

Precast concrete implementation in Indonesia is supported by sufficient amounts of equipment, such as gantry cranes, tower cranes, mobile cranes, etc., for lifting heavy precast panels. Many *Rusunawa* projects are located in remote area, but adequate amounts of equipment are available. Some of the important remarks in the interview sessions regarding opportunity technical quality are set out in Table 4-8.

Table 4-8.Remarks made in interview about opportunity technical quality

Remarks	SWOT Factors
CS1: "*Nothing is impossible. We have projects in Entikong, Bau-bau, Tarakan (remote area in Indonesia), they can build with precast.*"	Availability of equipment
CT2: "*The heavy equipment in Indonesia is available sufficiently. So it is not a problem to work with precast.*"	

Unfortunately, there is a threat of different quality and availability of material to produce good precast concrete quality. Materials from different regions possess different characteristic, therefore the formula for making concrete must be different in each region. This is a challenge to practitioners to design different types of construction components in different region, in order to avoid the high costs of transporting materials between regions. Some of the important remarks in the interview sessions regarding threat technical quality is set out in Table 4-9.

Table 4-9.Remarks made in interview about threat technical quality

Remarks	SWOT Factors
CT1: "*The quality and availability of material are different in each region.*"	Differences in quality and quantity of available materials
GV4: "*Every region has different characteristic of material, therefore design formula for concrete must be different.*"	

4.3.5 Implementation and Enforcement

Implementation and enforcement are supporting factors to achieve success implementation of precast concrete. The support should not only come from the Government, but also from stakeholder through professional organization and the rapid change of industrialization. The government supports the development of precast concrete through Regulation of the Minister of Civil Works number 05/PRT/M/2007 about Technical Guidelines of Vertical High-Rise Low-Costs Housing Constructions. The regulation recommends the use of precast concrete for construction. Therefore, this regulation is not mandatory. However, there is policy to use precast concrete for vertical low-cost housing for the project under Ministry of Civil Works.

In general, the precast and pre-stressed concrete industry was established by the Ministry of Public Works and Human Settlements to be a cornerstone of the Indonesian construction industry upon entering the ASEAN 2015 single market and the global market in 2020. Therefore, Indonesian Experts of Precast and Pre-stressed Concrete Association (IAPPI) in cooperation with the Ministry of Public Works and Human Settlements should facilitate engineers who are ready for training. Several training programs have already been conducted for construction supervisors and designers of precast concrete for building.

The training includes but not limited to, code of ethics and standards of professional conduct. The principles of the design of precast concrete consists of integrated design of architecture, structure and mechanical electrical and plumbing, seismic design and cost analysis, precast concrete construction management, precast concrete materials, introduction of existing precast concrete systems and codes, production, storage, handling, transportation, erection and installation of precast concrete, material and production quality control, and handling and erection quality control. The participants also have to examine case studies and visit to the Human Settlement research and development laboratories of the Ministry of Public Works and Human Settlements.

IAPPI also offers aid in developing precast concrete technology, and guidance in design, laboratory test, certification, socialization, and mock-ups for building projects. Since the formation of IAPPI in 1999, up to 62 precast concrete systems invented, patented and adopted in building project in Indonesia.

The high need of industrialization also encourages the development of precast concrete in Indonesia. According to the website of the Public Works and Human Settlement Ministry (PU, 2014), by the year 2014, the housing backlog reached fifteen million units. The previous year's backlog was twelve million units. The government has established the target of constructing 440 thousand new housing units per year (PU, 2014). Such a large target should be supported by construction technology with good quality, fast completion times, and reasonably economical construction costs.

The presence of Indonesian National Standard (SNI) about precast concrete technology is important as the guideline for stakeholders who want to get involved in precast concrete business. Currently there are two SNI related to precast load bearing wall system:

- SNI 7832:2012 for Calculation Procedure for Precast Concrete Work Unit for Building Construction. This standard contains a material building index and a labor index needed in each unit of work corresponding to technical work specifications of precast concrete work. It covers the production of half and full precast concrete, erection of precast concrete construction up to five-stories, connection of precast concrete construction and timber and phenol-film formwork.
- SNI 7833:2012 for Design Procedure for Precast Concrete and Pre-stressed Concrete for Buildings. This standard determines the minimum requirements of concrete structure component design and the performance of each structure erection to correspond to applicable standards of general building. This standard also covers the evaluation of existing concrete structure strength. For a concrete structure f_c cannot be less than 17 MPa. There is no maximum value defined for f_c, unless it is governed by specific regulations.

Some of the important remarks in the interview sessions regarding opportunity implementation and enforcement are set out in Table 4-10.

However, the existing regulations need to be improved. Although the Ministry of Public Works has issued a policy regarding pre-casting, it has not followed up with any local regulations. The Indonesian government's work unit that is responsible for *Rusunawa*, still has limited knowledge of precast concrete technology. Therefore, there is a tendency of unwillingness to select a single method of construction (conventional, precast, or formwork). The decisions are based on which system offers the best quality with the lowest cost and most reasonable construction time.

Moreover, the government's anti-seismic regulation standard requires that new technology, such as precast concrete system, undergo rigorous testing before any approval or licences from ministerial committee are granted. This encourages manufacturers to invest heavily in research and development to ensure high levels of earthquake resistance. As a result, the joint systems become complicated, making the installation of component more difficult and time consuming.

Table 4-10.Remarks made in interview about opportunity implementation and enforcement

Remarks	SWOT Factors
CS1: "*This regulation does not have law enforcement. If a region wants to implement precast for its Rusunawa project, it has put regulation under its local regulation. However, Rusunawa project under Public Works Ministry is enforced the adoption of precast concrete.*"	Ministerial regulation support
GV1: "*This regulation is not a requirement. It is only guideline to get faster project completion.*"	
CS2: "*The regulation at least can support precaster to run their business in term of recommended material so it will be known publicly.*"	
CS2: "*The opportunity of precast concrete development is number of trainings conducted several times in a year by IAPPI in cooperation with Public Work Ministry.*"	Available routine training by IAPPI
CT2: "*The presence of IAPPI is great since it can facilitate the development of precast industry. New invention will be supported in cooperate with Public Works Ministry Research Center. Therefore, precast technology will continue to grow.*"	IAPPI facilitation of developing precast concrete systems
GV1: "*The demand to provide houses in big cities are growing, while land availability are limited. People want to have good facilities, good qualities and fast construction time. We are now arranging strategic plan for 2015 – 2019 which leads to industrialization since the society is smarter and has higher demand of house*."	Higher needs for industrialization
CS1: "*SNI provides standard to produce economical product. It serves as a formal basis as a guideline in implementing precast concrete.*"	Indonesian National Standard support

There is also no reward or penalty if a project does or does not use precast concrete system. The government as the owner of *Rusunawa* project should be clear in giving direction in precast concrete project. Without any requirements in the bidding or contract, the contractor will use conventional methods, which is more familiar with the process of construction and financing.

The design of precast concrete components must take into account the quality standards and the durability of the precast components. The latter means possible construction methods with existing resources and site access restriction. Both must be met by the design standards in order to achieve the benefits of precast concrete technology. For example, the design of a precast concrete panel that has an opening, must not only fulfill structural requirements, but also must pay attention to the capability of the lifting equipment and the method of installation. Otherwise, defects and damages might be occured that render the component useless.

Currently, Indonesian employs unit price analysis and structural design standards. Other standards and guidelines for delivery, handling and storage, installation, and common defects and remedies are not yet available. However, these are important for practitioners to understand the unique situations in Indonesia.

Another threat is the restriction of existing infrastructure. Transporting large and heavy panels is usually very complex and costly. The potential problems are transportation permits, overhead obstructions, special vehicles and access road capacities to the site. There is uncertainty, regarding the transportation of components of the same type, and these may be delivered in different ways to different projects.

Some of the important remarks in the interview sessions regarding threat implementation and enforcement are set out in Table 4-11.

Table 4-11.Remarks made in interview about threat implementation and enforcement

Remarks	**SWOT Factors**
CS1: "*There is resistance from some government to implement precast technology, because they already have 'business' in conventional method and they do not want to lose the scheme*."	Lack of government incentives, directives and promotion
CS2: "*There are lack supervision and implementation from government. In terms of implementation, government funding for project are still experiencing delays, hence construction time will be the same with the conventional project. In term of supervision, there is lack of commitment from government hence susceptible to fraud.*"	
MN1: "*The standardization is not yet optimum. For example there is no reference unit price of precast for several materials such as steel.*"	Lack of integrated standardization
CS2: "*The technical requirement somehow excessive. For example the requirement of live load is too much (150 kg/m^2). Logically in 20 m^2 unit of Rusunawa occupied by 8 persons plus furniture and so on will not reach 6000 tons.*"	
CT2: "*Sometimes there are problems to deliver the component in remote areas because of road and bridge restriction. We experienced cannot pass the bridge because the capacity is very small.*"	Road and bridge restrictions

4.4 Conclusion

This chapter presents the results of the analysis of the data obtained from semi-structured interviews. It shows the situation of each factor in Indonesia by analysing the responses from the experienced respondent. There are 33 SWOT factors that have been listed (Table 4-12) and discussed thoroughly in this chapter. This qualitative SWOT factor analysis is further will be analysed in quantitative way and will be presented in the next chapter.

Table 4-12.The SWOT factors of precast load bearing wall implementation for low cost housing in Indonesia

No	SWOT Factors	Sustainability Criteria
	Strengths	
1	Smaller on-site area and staging space required	Economical value
2	More simplicity	Technical quality
3	Work in parallel	Economical value
4	Less scaffolding and formwork	Economical value
5	More success in meeting quality specifications	Economical value
6	Less labor required	Economical value
7	More efficient material usage	Ecological performance
8	Cleaner construction sites	Ecological performance
9	Greater job security	Social equity and culture
10	More highly durable buildings	Technical quality
11	Compensation for earthquake reduction factor	Technical quality
	Weaknesses	
12	Repetitious designs	Economical value
13	Higher transportation costs	Economical value
14	Licensing fees	Economical value
15	Higher initial investments	Economical value
16	Heavy equipment dependent	Economical value
17	More complex connection designs	Technical quality
18	Greater loading difficulties for big components or long spans	Technical quality
19	Greater difficulties in making changes during construction	Technical quality
	Opportunities	
20	Availability of equipment	Technical quality
21	Available routine training by IAPPI	Implementation and enforcement
22	Ministerial regulation support	Implementation and enforcement
23	Indonesian National Standard support	Implementation and enforcement
24	Higher needs for industrialization	Implementation and enforcement
25	IAPPI facilitation of developing precast concrete systems	Implementation and enforcement
	Threat	
26	Foreman-handyman culture difficult to change	Social equity and culture
27	Limited public awareness	Social equity and culture
28	Development centralized in Java Island	Social equity and culture
29	Shortage of expertise and skilled labor	Social equity and culture
30	Differences in quality and quantity of materials	Technical quality
31	Lack of integrated standardization	Implementation and enforcement
32	Lack of government incentives, directives and promotion	Implementation and enforcement
33	Road and bridge restrictions	Implementation and enforcement

CHAPTER 5
SURVEY INSTRUMENTS

5.1 Introduction

This chapter portrays the main survey instrument in the research. Survey instrument is a tool to obtain data from respondents in scientific manner. It is important to understand the type and structure of survey instrument to be used in order to provide data analysis easily and achieve survey objective correctly. This research involves questionnaire as the survey instrument. The questionnaire design, questionnaire response and questionnaire validity are discussed thoroughly in this chapter.

5.2 Questionnaire Design

The questionnaire consisted of four parts. The first part captured the details of respondents' demography such as background and level of experience. The second part was evaluation of SWOT factors by using rating scale. The third part was pairwise comparison to get the weight score of factors within SWOT group. The last part was open-ended question to further comments and suggestions for the research. The SWOT factors were referred to the 33 SWOT factors that have been listed in previous chapter. The questionnaire was developed as easy as possible, so the respondents can answer conveniently. Therefore, it was delivered in Indonesian language since the target respondents are stakeholder group in Indonesia. The questionnaire document set can be seen in Appendix B.

5.2.1 Evaluation of SWOT Factors

The evaluation of SWOT factors aimed to obtain the response of stakeholders toward the particular factor. The questionnaire utilized ordinal rating scale as the scale of measurement. The scale of measurement were given as scale *one* represents *poor (strongly disagree)* to scale *five* represents *outstanding (strongly agree)*, where scale *three* represents *average*. In a simple way the respondents were asked if they agree with the factor or disagree. For example we had the factor 'smaller on site area and staging space required' (*S.EV.1*) under strength category. The respondent will be asked how they response toward the factor. If they were disagreed of *S.EV.1* as strength, then they can opt scale *one* or *two* and it can be interpreted the response towards the factor was poor, *vice versa*. The same concept also applied to weakness, opportunity and threat category.

5.2.2 Pairwise Comparison of SWOT Factors

The pairwise comparison of SWOT factors aimed to get the stakeholder group perception toward level of importance of the factor. The pairwise comparison questionnaire had four main parts namely: pairwise comparison under strength category, pairwise comparison under weakness category, pairwise comparison under opportunity category, and pairwise comparison under threat category. Figure 5-1 illustrates the structure of pairwise comparison questionnaire and describes in the following paragraphs.

Pairwise comparison under strength category has eleven factors to be compared. These factors were derived from four strength-sustainability-criteria namely: economic value, ecological performance, social equity and culture and technical quality. Each criterion has six, two, one and two factors respectively. Therefore, the respondents have four groups of pairwise comparison matrices under the strength category: pairwise comparison matrix of strength-sustainable-criteria, pairwise comparison matrix of strength economic value, pairwise comparison matrix of strength ecological performance, and pairwise comparison matrix of strength technical quality.

Pairwise comparison under weakness category has eight factors to be compared. These factors were derived from two weakness-sustainability-criteria namely: economic value and technical quality. The first has five factors and the latter has three factors. Therefore, the respondents have three groups of pairwise comparison matrices under the weakness category: pairwise comparison matrix of weakness-sustainability-criteria, pairwise comparison matrix of weakness economic value, and pairwise comparison matrix of weakness technical quality.

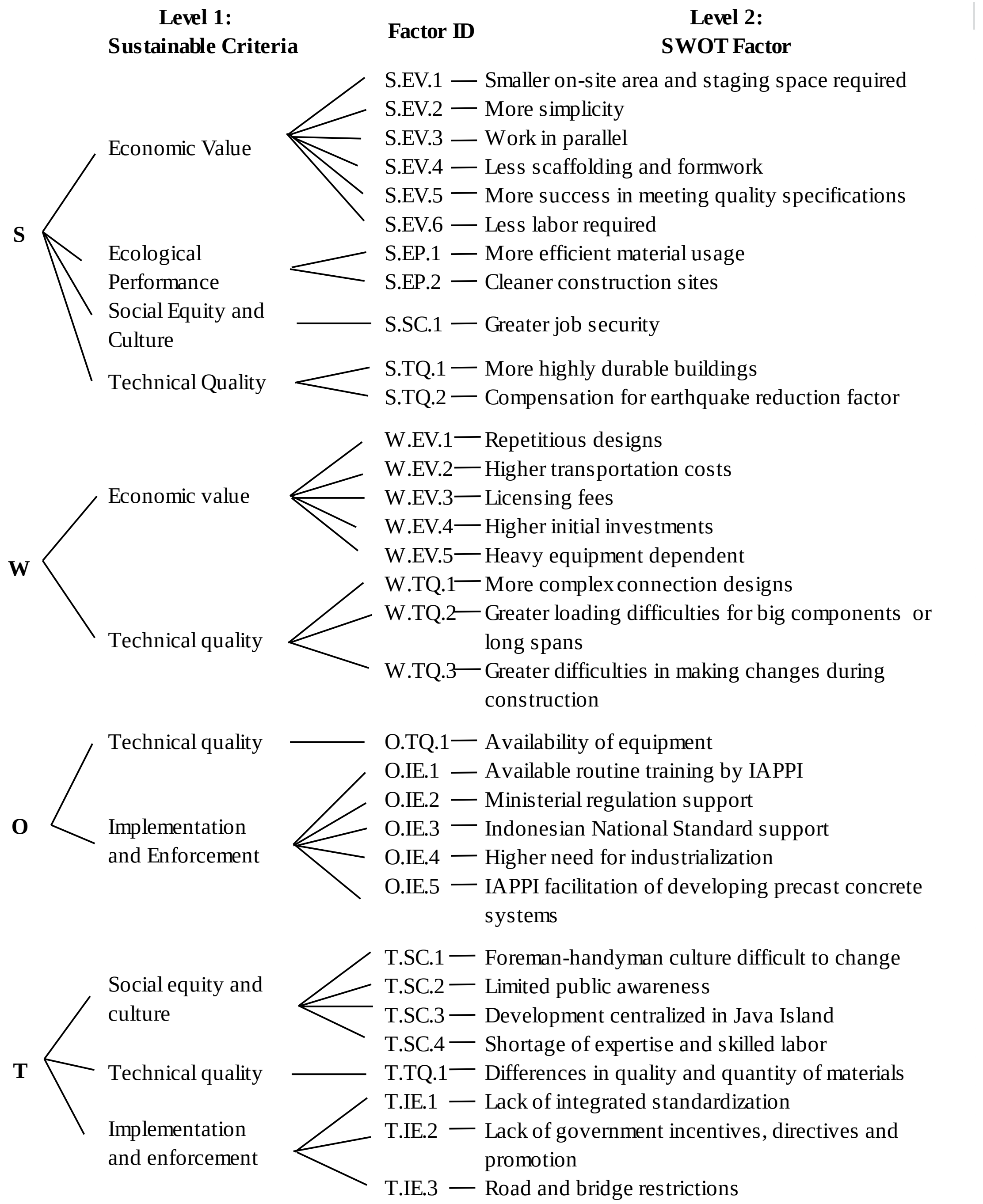


Figure 5-1. Pairwise comparison questionnaire structure

Pairwise comparison under opportunity category has six factors to be compared. These factors were derived from two opportunity-sustainability-criteria namely: technical quality and implementation and enforcement. The first has one factor and the latter has five factors. Therefore, the respondents have two groups of pairwise comparison matrices under the opportunity category: pairwise comparison matrix of opportunity-sustainability-criteria, and pairwise comparison matrix of opportunity implementation and enforcement.

Pairwise comparison under threat category has eight factors to be compared. These factors were derived from three threat-sustainability-criteria namely: social equity and culture, technical quality, and implementation and enforcement. They had four, one, and three factors respectively. Therefore, the respondents had three groups of pairwise comparison matrices under the threat category: pairwise comparison matrix of threat-sustainability-criteria, pairwise comparison matrix of threat social equity and culture, and pairwise comparison matrix of threat implementation and enforcement.

The answers of the respondents were analysed by Analytical Hierarchical Process developed by Saaty (1980). Table 5-1 illustrates the example of strength-sustainable-criteria pairwise comparison matrix of a respondent. Each pairwise comparison matrix of each respondent was checked for the Consistency Ratio. If the Consistency Ratio is below the recommended level of 0.1 (Saaty, 1980), then the result is consider as consistent and valid to be used for further analysis. The complete tabulation of valid answer is forward in section 5.5 Questionnaire Validity.

Table 5-1.Example of strength-sustainable-criteria pairwise comparison matrix (respondent 6)

Strength Sustainability Criteria	Economic Value	Ecological Performance	Social equity and Culture	Technical Quality
Economic Value	1.00	7	5	1/5
Ecological Performance		1.00	1/5	1/5
Social equity and Culture			1.00	1/5
Technical Quality				1.00

The pairwise judgments of the valid answers were combined using geometric mean at each level of AHP structure and then put into the pairwise comparison matrix. The next step was to derive the scale of priorities (or weights). The scale of priorities was obtained by solving for the principal eigenvector of the matrix and then normalizing the result. Table 5-2 illustrates the example of weight priority composition of factors under strength category after aggregation for each level. The local weight of level 1 (column 2) was multiplied by local weight of level 2 (column 5) to obtain global weights (column 6). The number of factors directly affects weight shared under the criteria. The factor having less sibling could share higher weight comparing to the one having more sibling.

Table 5-2.Example of weight priority composition of factors under strength category (respondent 6)

1	2	3	4	5	6
Sustainability Criteria	**Local weights**	**Factor ID**	**SWOT Factors**	**Local weights**	**Global weights**
Economic Value	0.275	S.EV.1	Smaller on-site area and staging space required	0.03	0.008
		S.EV.2	More simplicity	0.15	0.041
		S.EV.3	Work in parallel	0.05	0.014
		S.EV.4	Less scaffolding and formwork	0.42	0.115
		S.EV.5	More success in meeting quality specifications	0.09	0.024
		S.EV.6	Less labor required	0.27	0.073
Ecological Performance	0.046	S.EP.1	More efficient material usage	0.83	0.039
		S.EP.2	Cleaner construction sites	0.17	0.008
Social Equity and Culture	0.113	S.SC.1	Greater job security	1.00	0.113
Technical Quality	0.565	S.TQ.1	More highly durable buildings	0.83	0.471
		S.TQ.2	Compensation for earthquake reduction factor	0.17	0.094

5.3 Questionnaire Response Rate

There were four groups of respondents identified as the key stakeholders in precast concrete implementation. The stakeholders were selected based on their experience; especially in low-cost housing projects (*Rusunawa*) that used precast concrete. The stakeholders consisted of project owners, manufacturers, consultants/designers and contractors that have experienced in constructing *Rusunawa* by precast concrete technology. In this case, the owners were the *Rusunawa* task forces and Research and Development of Human Settlement of the Ministry of Public and Human Settlement, the Government of Indonesia.

A contact list of companies and professionals which have experience in precast concrete project in Indonesia was generated. The list mainly comes from database of Association of Precast and Prestressed Company in Indonesia (AP3I) and Association of Precast and Prestressed Expert in Indonesia (IAPPI). The list also not limited from the related government agencies, feedback from previously identified stakeholders and comprehensive internet search. A total of 100 questionnaires were introduced and distributed to survey participants with a cover letter. The cover letter is important for explaining the purpose of the study and assuring anonymity. By 6^{th} February 2015, thirty-six questionnaires had been returned and were evaluated before being used in the analysis.

The data collection of questionnaire survey was conducted in two ways, namely mailed questionnaire and face-to-face interviews. The total response rate for the survey from both methods was 36%. According to Akintoye (2000), this level of response rate is acceptable based on the norm in the construction industry that ranges from 20% to 30%. The details on the response received in this research are provided below.

Mailed and self-administered questionnaires: The questionnaires were mailed on October 2014 to January 2015. The questionnaires was electronically sent in total 73 address consists of 39 company email listed in AP3I and 34 personal emails. The returned questionnaire from this method was 9 respondents which all come from personal email. Therefore, the response rate for this distribution method was only 12.33%.

Face-to-face interviews: Due to budget and time constraints, the researcher only managed to conduct face-to-face interview with 27 respondents. Face to face interview was conducted two times, on 13 – 31 October 2015 and 12 – 24 January 2015. The response rate was very good because the researcher had made an individual appointment with the respondent and explained the survey in detail and answered any unclear information during the meeting. The percentage of response rate was 100% for this method.

5.4 Respondents Profiles

The respondents represented the stakeholders who were selected based on their experience in precast concrete such as, but not limited to, government low-cost housing projects (*Rusun*). The respondents were required to provide their background and experience in the first part of the questionnaire. Figure 5-2 illustrates a breakdown of the thirty-six of the valid respondents based on organization types.

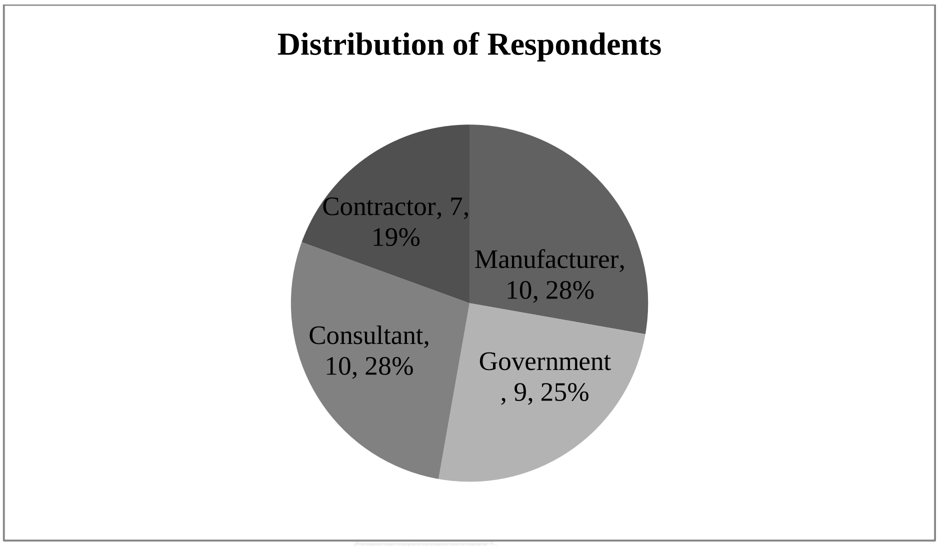


Figure 5-2.Distribution of respondents based on organization type

There were four groups of respondents participated in this research. The manufacturer group and the consultant/designer group has the highest number of respondents, each representing 28% of the total number respondents in this research. This was followed by respondents in the government group (25%) and the contractor group (19%). All the respondents have experience in construction work and among them 69% have been involved in precast concrete (in general, not particular to only precast load bearing wall system) project for more than 5 years. The distribution of respondents' experience in construction industry and precast concrete projects shows in Figure 5-3

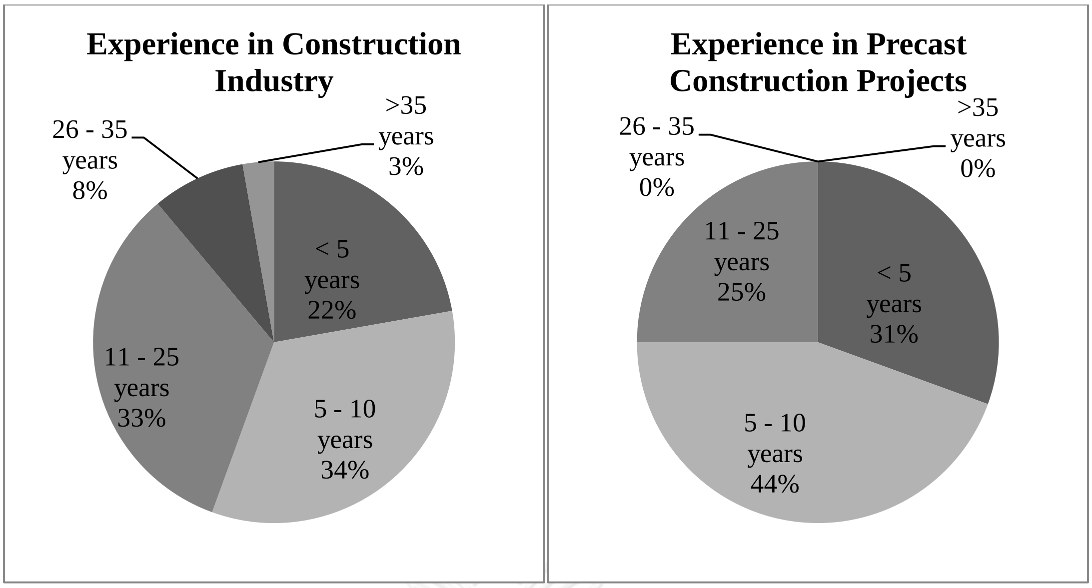


Figure 5-3.Distribution of respondents' experience in construction industry and precast concrete projects

5.5 Questionnaire Validity

Questionnaire validity was evaluated by considering whether the survey questions were fully answered, whether there were any obvious irrational answers such as giving the same score for all items, and whether the profile of the respondent showed limitations such as no experience in precast concrete project. All the thirty-six completed questionnaires, were considered as valid and can be used to analyse further for the second part of the questionnaire (Evaluation of SWOT Factors). However, the validity for the third part of the questionnaire (Pairwise Comparison of SWOT Factors) is discussed below and summarized in Table 5-3.

Table 5-3.Summary of pairwise comparison questionnaire valid response

Pairwise Comparison Matrix	Valid Answer				
	Global Industry	G1	G2	G3	G4
Strength sustainable criteria	30	9	9	5	7
Strength economic value	28	9	7	4	8
Strength ecological performance	36	9	10	7	10
Strength technical quality	36	9	10	7	10
Weakness sustainable criteria	36	9	10	7	10
Weakness economic value	30	7	7	7	9
Weakness technical quality	31	7	9	6	9
Opportunity sustainable criteria	36	9	10	7	10
Opportunity implementation and enforcement	28	7	8	4	9
Threat sustainable criteria	34	7	10	7	10
Threat social equity and culture	33	9	9	7	8
Threat implementation and enforcement	34	9	9	6	10

*Completed questionnaire for each group
Global Industry = 36; G1 (Government) = 9; G2 (Manufacturer) = 10; G3 (Contractor) = 7; G4 (Consultant/Designer) = 10

5.5.1 Questionnaire Validation of Global Industry

Strength Category: Among thirty-six completed questionnaires, thirty were consistent to the pairwise comparison of strength-sustainability-criteria, twenty-eight were consistent to the pairwise comparison of strength economic value, thirty-six were consistent for pairwise comparison of strength ecological performance, and thirty-six were consistent for pairwise comparison of strength technical quality. The consistent answers were considered valid to be analysed further.

Weakness Category: Among thirty-six completed questionnaires, thirty-six were consistent to the pairwise comparison of weakness-sustainable-criteria, thirty were consistent to the pairwise comparison of weakness economic value, and thirty-one were consistent for pairwise comparison of weakness technical quality. The consistent answers were considered valid to be analysed further.

Opportunity Category: Among thirty-six completed questionnaires, thirty-six were consistent to the pairwise comparison of opportunity-sustainable-criteria, and twenty-eight were consistent to the pairwise comparison of opportunity implementation and enforcement. The consistent answers were considered valid to be analysed further.

Threat Category: Among thirty-six completed questionnaires, thirty-four were consistent to the pairwise comparison of threat-sustainable-criteria, thirty-three were consistent to the pairwise comparison of threat social equity and culture, and thirty-four were consistent to the pairwise comparison of threat implementation and enforcement. The consistent answers were considered valid to be analysed further.

5.5.2 Questionnaire Validation of Government

Strength Category: Among nine completed questionnaires, nine were consistent to the pairwise comparison of strength-sustainability-criteria, nine were consistent to the pairwise comparison of strength economic value, nine were consistent for pairwise comparison of strength ecological performance, and nine were consistent for pairwise comparison of strength technical quality. The consistent answers were considered valid to be analysed further.

Weakness Category: Among nine completed questionnaires, nine were consistent to the pairwise comparison of weakness-sustainable-criteria, seven were consistent to the pairwise comparison of weakness economic value, and seven were consistent for pairwise comparison of weakness technical quality. The consistent answers were considered valid to be analysed further.

Opportunity Category: Among nine completed questionnaires, nine were consistent to the pairwise comparison of opportunity-sustainable-criteria, and seven were consistent to the pairwise comparison of opportunity implementation and enforcement. The consistent answers were considered valid to be analysed further.

Threat Category: Among nine completed questionnaires, seven were consistent to the pairwise comparison of threat-sustainable-criteria, nine were consistent to the pairwise comparison of threat social equity and culture, and nine were consistent to the pairwise comparison of threat implementation and enforcement. The consistent answers were considered valid to be analysed further.

5.5.3 Questionnaire Validation of Manufacturer

Strength Category: Among ten completed questionnaires, nine were consistent to the pairwise comparison of strength-sustainability-criteria, seven were consistent to the pairwise comparison of strength economic value, ten were consistent for pairwise comparison of strength ecological performance, and ten were consistent for pairwise comparison of strength technical quality. The consistent answers were considered valid to be analysed further.

Weakness Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of weakness-sustainable-criteria, seven were consistent to the pairwise comparison of weakness economic value, and nine were consistent for pairwise comparison of weakness technical quality. The consistent answers were considered valid to be analysed further.

Opportunity Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of opportunity-sustainable-criteria, and eight were consistent to the pairwise comparison of opportunity implementation and enforcement. The consistent answers were considered valid to be analysed further.

Threat Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of threat-sustainable-criteria, nine were consistent to the pairwise comparison of threat social equity and culture, and nine were consistent to the pairwise comparison of threat implementation and enforcement. The consistent answers were considered valid to be analysed further.

5.5.4 Questionnaire Validation of Contractor

Strength Category: Among seven completed questionnaires, five were consistent to the pairwise comparison of strength-sustainability-criteria, four were consistent to the pairwise comparison of strength economic value, seven were consistent for pairwise comparison of strength ecological performance, and seven were consistent for pairwise comparison of strength technical quality. The consistent answers were considered valid to be analysed further.

Weakness Category: Among seven completed questionnaires, seven were consistent to the pairwise comparison of weakness-sustainable-criteria, seven were consistent to the pairwise comparison of weakness economic value, and six were consistent for pairwise comparison of weakness technical quality. The consistent answers were considered valid to be analysed further.

Opportunity Category: Among seven completed questionnaires, seven were consistent to the pairwise comparison of opportunity-sustainable-criteria, and four were consistent to the pairwise comparison of opportunity implementation and enforcement. The consistent answers were considered valid to be analysed further.

Threat Category: Among seven completed questionnaires, seven were consistent to the pairwise comparison of threat-sustainable-criteria, seven were consistent to the pairwise comparison of threat social equity and culture, and six were consistent to the pairwise comparison of threat implementation and enforcement. The consistent answers were considered valid to be analysed further.

5.5.5 Questionnaire Validation of Consultant/Designer

Strength Category: Among ten completed questionnaires, seven were consistent to the pairwise comparison of strength-sustainability-criteria, eight were consistent to the pairwise comparison of strength economic value, ten were consistent for pairwise comparison of strength ecological performance, and ten were consistent for pairwise comparison of strength technical quality. The consistent answers were considered valid to be analysed further.

Weakness Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of weakness-sustainable-criteria, nine were consistent to the pairwise comparison of weakness economic value, and nine were consistent for pairwise comparison of weakness technical quality. The consistent answers were considered valid to be analysed further.

Opportunity Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of opportunity-sustainable-criteria, and nine were consistent to the pairwise comparison of opportunity implementation and enforcement. The consistent answers were considered valid to be analysed further.

Threat Category: Among ten completed questionnaires, ten were consistent to the pairwise comparison of threat-sustainable-criteria, eight were consistent to the pairwise comparison of threat social equity and culture, and ten were consistent to the pairwise comparison of threat implementation and enforcement. The consistent answers were considered valid to be analysed further.

5.6 Conclusion

This chapter reported the survey instrument of the main research. The main survey was involved questionnaire to evaluate the response of stakeholder group toward SWOT factors by rating scale and to evaluate importance levels of SWOT factors by pairwise comparison. The respondents participated in the survey were comes from four different stakeholder groups, namely Government as the owner of *Rusunawa* project, Manufacturers, Contractors and Consultants/Designers. There were thirty-six completed questionnaires that are available to be analysed further.

CHAPTER 6
SWOT FACTORS EVALUATION

6.1 Introduction

The evaluation of SWOT factors aimed to obtain the stakeholder group perception in responding the strategic factors. As described in Chapter 5, the respondents responded the evaluation of SWOT factors by selecting rating scale for each factor. There were thirty-six valid answers available to be analysed further. This chapter provides the analysis of the valid answer in statistical manner.

6.2 Descriptive Statistics

The results shown in Table 6-1 indicate that under strength category, the respondents selected “agree” to “strongly agree” with the mean value of more than 4.00 toward eight factors. The factors in orderly manner were “less scaffolding and formwork” (highest mean value of 4.58), “more efficient material usage” (mean value = 4.33), “work in parallel” (mean value = 4.33), “cleaner construction sites” (mean value = 4.30), “more simplicity” (mean value = 4.25), “more success in meeting quality and specifications” (mean value = 4.22), “less labor required” (mean value = 4.19), and “more highly durable buildings” (mean value = 4.14). There were three factors which did not get good responses from the respondents with the mean value of less than 4.00. The factors are “greater job security” (mean value = 3.97), “smaller on-site area and staging space required” (mean value = 3.88), and “compensation for earthquake reduction factor” (mean value = 3.41). The lower rating given to such factors were in accordance to the fact that (1) Indonesian businesses require labor intensive work where most of companies prefer to have labor outsourcing scheme, (2) most precast concrete project are set-up the temporary factory near or on the site, thus more space is needed for production and storage, (3) most regions in Indonesia are located in seismically active area, therefore, there is scepticism about the capacity of precast load bearing wall to resist earthquake.

Under weakness category, there were three factors, which had the mean value of more than 4.00. The factors were considered as the weakness for precast concrete implementation. The factors were “heavy equipment dependent” (mean value = 4.56), “higher initial investments” (mean value = 4.28), “greater difficulties in making changes during construction” (mean value = 4.00). Although heavy equipment is required in most of construction projects, it is increasingly becoming a problem in precast construction project. Precast concrete construction project is not only depended on heavy equipment to lift the concrete panel, but also more depended on several other things, including 1) equipment to lift precast panel and 2) special skills in handling the precast panel using appropriate equipment. The two latter factors are related with substantial amount of money at initial phase, whether to set up production plant and/or the construction itself. The detail engineering design may change during the on-going construction which is sometime happened in order to adapt the availability of budget at the time. The other factors were considered as less weakness of the mean value less than 4.00, included “higher transportation cost” (mean value = 3.86), “more complex connection designs” (mean value = 3.78), “repetitious design” (mean value = 3.72), “greater loading difficulties for big components or long spans” (mean value = 3.58), and “licensing fee” (mean value = 3.28).

The response towards opportunity of precast concrete implementation was ‘only’ good. It can be concluded from the mean value of nearly equal to 4.00, which were “availability of equipment” (mean value = 4.06), “Indonesian National Standard support” (mean value = 4.03), and “higher needs of industrialization” (mean value = 4.03). The other factors which had mean value below 4.00, respectively, “ministerial regulation support” (mean value = 3.94), “IAPPI facilitation of developing precast concrete systems” (mean value = 3.86), and “available routine training by IAPPI” (mean value = 3.69). Accordingly, it can be interpreted that the factors under opportunity category still had room to improve the performance so the precast concrete implementation can be more flourish and more competitive.

According to the results, none of the factor was under threat category reach mean value of 4.00. It means the factors that had been listed were not significant enough to be considered as threats. The highest mean value of 3.92 was “limited public awareness”, while the lowest value of 3.31 was “lack of government incentives, directives and promotion”. It seems that precast load bearing wall application was still seized by its internal weaknesses than its external threats.

Standard deviation showed how much variation exists from the mean evaluated in the analysis. The value of standard deviation was mostly below one, thus representing good data accuracy in this research.

The next step *t*-test analysis was employed to identify the significant of mean value for each factor ((Ekanayake and Ofori, 2004); (Wong and Li, 2006)). The rule of *t*-test set out as follows:

The null hypothesis H_0: $\mu \leq \mu_0$ against the alternative hypothesis H_1: $\mu > \mu_0$, where μ was the population mean. The decision rule to reject H_0 when the calculated t value was larger than $t_{(n-1,\, \alpha)}$, where the random variable $t_{(n-1,\, \alpha)}$ follows t-distribution table with n is the sample size, $n - 1$ is degrees of freedom and α is the significance level.

In this research the value of μ0 was fixed at ‘3’ because the population mean of all SWOT factors in this research is above 3 that represents the opinion of respondents are in the range of ‘average’, ‘agree’, and ‘strongly agree’. The significance level, α was set at 0.05 that implied there was 95% certainty not due to chance. Therefore the value of $t_{(35,\, 0.05)}$ is 1.6896.

According to the results in Table 6-1, all the *t*-value of SWOT factors was larger than 1.6896, hence the null hypothesis that the population mean of SWOT factors was ≤ 3 was rejected and the alternative hypothesis that the population mean of SWOT factors was > 3 was accepted. The only exception was happened for the factor ‘licensing fees’ that its *t*-value was smaller than 1.6896, thus, these factor can be eliminated.

Table 6-1.Mean value and standard deviation of SWOT factors

SWOT Factors	Mean	Std. Deviation	t-value*	Sig. 1-tailed (p-value)
Strength				
Less scaffolding and formwork	4.58	0.60	15.74	0.000
More efficient material usage	4.33	0.79	10.09	0.000
Work in parallel	4.33	0.72	11.16	0.000
Cleaner construction sites	4.31	0.75	10.46	0.000
More simplicity	4.25	0.77	9.74	0.000
More success in meeting quality specifications	4.22	0.83	8.82	0.000
Less labor required	4.19	0.98	7.31	0.000
More highly durable buildings	4.14	0.93	7.34	0.000
Greater job security	3.97	0.94	6.20	0.000
Smaller on-site area and staging space required	3.89	1.04	5.15	0.000
Compensation for earthquake reduction factor	3.42	1.05	2.38	0.012
Weakness				
Heavy equipment required	4.56	0.61	15.38	0.000
Higher initial investments	4.28	0.81	9.41	0.000
Greater difficulties in making changes during construction	4.00	1.01	5.92	0.000
Higher transportation costs	3.86	0.96	5.38	0.000
More complex connection designs	3.78	0.93	5.02	0.000
Repetitious designs	3.72	1.03	4.20	0.000
Greater loading difficulties for big components or long spans	3.58	1.18	2.97	0.003
Licensing fees	3.28	1.11	1.50	0.071
Opportunity				
Availability of equipment	4.06	1.07	5.93	0.000
Indonesian National Standard support	4.03	1.00	6.17	0.000
Higher needs for industrialization	4.03	0.77	7.97	0.000
Ministerial regulation support	3.94	0.95	5.94	0.000
IAPPI facilitation of developing precast concrete systems	3.86	0.90	5.75	0.000
Available routine training by IAPPI	3.69	1.01	4.13	0.000
Threat				
Limited public awareness	3.92	0.77	7.14	0.000
Shortage of expertise and skilled labor	3.89	0.85	6.24	0.000
Foreman-handyman culture difficult to change	3.81	1.12	4.33	0.000
Differences in quality and quantity of materials	3.61	1.23	2.99	0.003
Road and bridge restrictions	3.61	1.08	3.41	0.001
Lack of integrated standardization	3.61	0.99	3.69	
Development centralized in Java Island	3.56	1.05	3.16	0.002
Lack of government incentives, directives and promotion	3.31	0.95	1.93	0.031

*$\mu_0 = 3$, df = 35

6.3 Reliability of Test

The Cronbach Alpha was calculated to test the internal consistency of the scales in providing appropriate ratings for the listed factors. The internal consistency is referred to the degree to which the items measuring the same underlying construct (Pallant, 2007). The coefficient for alpha reliability is normally between 0 and 1. The minimum recommended level of Cronbach's alpha is 0.7 (Pallant, 2007), but values above 0.8 are often preferred (Nunnally, 1978). However, the Cronbach alpha values are quite sensitive to the number of items in the scale. It is common to find quite low Cronbach values (e.g. 0.5) when there are short scales with fewer than ten items (Pallant, 2007). In this case it may be more appropriate to report the mean inter-item correlation for the items (Pallant, 2007). Briggs and Cheek (1986) recommend an optimal range for the inter-tem correlation. Table 6-2 illustrates the summary value of reliability analysis for each SWOT Category.

Table 6-2.Reliability test of SWOT category

SWOT Category	N Cases	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items	Mean inter-item correlation
Strength	36	0.853	0.865	11	0.368
Weakness	36	0.660	0.682	8	0.211
Opportunity	36	0.776	0.776	6	0.370
Threat	36	0.728	0.721	8	0.244

The strength, opportunity and threat category had Cronbach values more than 0.7 and had mean inter-item correlation between 0.2 and 0.4, indicating a very good internal consistency for the scales used in the study, and suggesting that reliable data has been obtained. However, the weakness category had Cronbach value slightly less than 0.7. Small number of items in the scales could be one reason of low Cronbach value. In this case, mean inter-item correlation of weakness category can meet the optimal range values, hence, the internal consistency of weakness category can be considered good.

6.4 Agreement on SWOT Factors

Kendall's coefficient of concordance (W) measures the agreement of respondents on ranked factors. If the test statistics, W, was 1, all survey respondents have been unanimous and assigned the same order to the list of factors. If W is 0, there is no agreement among the respondents. The hypothesis for concordance analysis is set up as:

H_0 = There is no agreement among respondents

H_1 = There is agreement among respondents

Table 6-3 illustrates the summary value of concordance analysis for each SWOT Category. Assuming alpha = 0.05, if the Chi-square value equals or exceeds that are shown in Appendix D for a particular level of significance and a particular value of $df = N - 1$, then the null hypothesis is rejected at the 0.05 level of significance (Siegel and Castellan, 1988).

In the case of strength category, the Chi-square value was 56.509 and it exceeded the value of significance level 0.05 with *df* 10 (18.31) allow to reject the null hypothesis. It can be concluded that there was agreement among respondents but on the low side (W = 0.157).

In the case of weakness category, the Chi-square value was 47.718 and it exceeded the value of significance level 0.05 with *df* 7 (14.07) allow to reject the null hypothesis. It can be concluded that there was agreement among respondents but on the low side (W = 0.189).

In the case of opportunity category, the Chi-square value was 9.170 and it was below the value of significance level 0.05 with *df* 5 (11.07) allow to accept the null hypothesis. It can be concluded that there was no agreement among respondents.

In the case of threat category, the Chi-square value is 14.209 and it is exceeds the value of significance level 0.05 with *df* 7 (14.07) allow to reject the null hypothesis. It can be concluded that there was agreement among respondents but on the low side (W = 0.056).

Table 6-3.Kendall's coefficient of concordance test

SWOT Category	N Cases	Kendall's *W*	Chi-Square	DF	Significance (p-value)
Strength	36	0.157	56.509	10	0.000
Weakness	36	0.189	47.718	7	0.000
Opportunity	36	0.051	9.170	5	0.102
Threat	36	0.056	14.209	7	0.048

The low value of W coefficient for each SWOT category was mean that the respondents had low agreement and even conflicted in determining the most significant factors. Therefore, further analysis of Kruskal-Wallis one-way ANOVA was used to improve the common understanding of the stakeholder.

Agreement across the four organizations are important to be identified before developing suitable strategy for sustainable implementation of precast concrete. It should be investigated in detail to get a clear picture of the inter-relationships between SWOT factors. Kendall's coefficient of concordance can identify the agreement levels, but it cannot investigate whether there are significant differences in the stakeholders' rankings of the significance level. Therefore, Kruskal-Wallis one-way ANOVA was applied to address this issue (Yunus, 2012).

The Kruskal-Wallis one-way ANOVA technique tests the null hypothesis that the *k* samples come from the same population or from identical populations with the same median (Siegel and Castellan, 1988). Therefore the hypothesis set up for this analysis is:

H_0 = There is no difference among the four groups of stakeholder in responding the SWOT factors

H_1 = The groups of stakeholder differ in responding the SWOT factors

According to Table 6-4, all the SWOT factors had x^2 value less than tabled value (7.82) in the Appendix D for a particular level of significance of 0.05 and a particular value of df = 3. Therefore, null hypothesis was accepted. It was mean that there was no difference among the four groups of stakeholder in responding the SWOT factors.

Table 6-4.Kruskal-Wallis statistic of SWOT factors

Factor ID	G1	G2	G3	G4	Kruskal wallis statistics (x^2)	p-value
S.EV.1	14.83	18.80	18.93	21.20	1.968	0.579
S.EV.2	17.56	18.70	20.93	17.45	0.652	0.884
S.EV.3	17.50	16.00	17.71	22.45	2.587	0.460
S.EV.4	17.44	15.85	20.14	20.95	2.017	0.569
S.EV.5	17.94	15.00	17.50	23.20	3.695	0.296
S.EV.6	15.61	17.25	20.36	21.05	1.941	0.585
S.EP.1	17.06	17.20	19.57	20.35	0.851	0.837
S.EP.2	16.94	17.65	22.36	18.05	1.443	0.695
S.SC.1	17.50	13.05	21.57	22.70	5.509	0.138
S.TQ.1	16.50	19.05	15.00	22.20	2.689	0.442
S.TQ.2	15.44	16.90	22.86	19.80	2.632	0.452
W.EV.1	17.44	17.15	17.79	21.30	1.091	0.779
W.EV.2	19.67	15.00	21.29	19.00	1.890	0.596
W.EV.3	15.67	21.10	20.71	16.90	1.928	0.587
W.EV.4	16.72	17.30	22.21	18.70	1.494	0.684
W.EV.5	16.06	17.30	23.07	18.70	2.633	0.452
W.TQ.1	23.50	19.50	13.21	16.70	4.640	0.200
W.TQ.2	21.72	13.20	17.86	21.35	4.421	0.219
W.TQ.3	18.11	17.75	14.71	22.25	2.488	0.477
O.TQ.1	13.17	19.00	19.86	21.85	3.910	0.271
O.IE.1	17.78	18.70	16.57	20.30	0.629	0.890
O.IE.2	17.33	18.05	17.00	21.05	0.953	0.813
O.IE.3	14.11	19.40	19.29	21.00	2.530	0.470
O.IE.4	14.44	19.20	14.14	24.50	6.870	0.076
O.IE.5	18.33	18.50	14.43	21.50	2.102	0.552
T.SC.1	19.83	13.30	23.07	19.30	4.289	0.232
T.SC.2	16.83	16.85	17.86	22.10	1.900	0.593
T.SC.3	17.61	19.15	18.86	18.40	0.129	0.988
T.SC.4	19.78	18.45	11.93	22.00	4.423	0.219
T.TQ.1	17.44	18.30	21.21	17.75	0.649	0.885
T.IE.1	13.89	15.75	22.29	22.75	5.433	0.143
T.IE.2	15.06	21.15	17.00	20.00	2.288	0.515
T.IE.3	16.56	18.30	17.93	20.85	0.916	0.822

*df for Kruskal-Wallis test = 3

G1 = Government; G2 = Manufacturer; G3: Contractor; G4 = Consultant

6.5 Conclusion

This chapter presents the analysis of SWOT factor evaluation by statistical analysis. From the result of descriptive mean value of each 33 SWOT factors, the value of standard deviation were mostly below 1, thus representing good data accuracy in this research. According to the one sample *t*-test result, the SWOT factors population mean above 3 was considered significant.

The value of Cronbach's alpha for strength, opportunity and threat category were more than 0.7 and had mean inter-item correlation between optimal value of 0.2 to 0.4, indicating a very good internal consistency for the scales used in the study, and suggesting that reliable data has been obtained. However the value of Cronbach's alpha for weakness category was less than 0.7 but the internal consistency was considered as good because the mean inter-item correlation value was 0.211.

In this research, there was agreement among respondents in responding the strength, weakness and threat category with the low value of Kendall's W coefficient. However, there was no agreement among respondents in responding the opportunity category. From the results of Kendall's W analysis can be concluded that the respondents had different preferences and even conflicts in determining the most significant factors. Therefore, further analysis of Kruskal-Wallis one-way ANOVA was used to improve the common understanding of the stakeholder. The Kruskal-Wallis one-way ANOVA test revealed that there was no significant difference between various stakeholder organizations for 33 SWOT factors.

CHAPTER 7
THE HYBRID METHOD OF SWOT-AHP ANALYSIS

7.1 Introduction

SWOT Analysis has been proven to be the most widely used in the first step of strategic planning (Davidovic and Jovanovic, 2012). The limitation of SWOT analysis, such as superficial and imprecise listing or an incomplete qualitative examination of internal and external factors (Kurttila *et al.*, 2000) were overcoming by quantifying the SWOT factors. One method of SWOT Analysis quantification is to summarized the internal and external strategic factors into IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) developed by Wheelen and Hunger (2012). However, there was a shortcoming of non-uniformity occur in applying the weights of key factors without a consistency test. Therefore Kurttila *et al.* (2000) and Stewart *et al.* (2002) combined the Analytic Hierarchy Process (AHP) with SWOT to provide a new hybrid method for improving the usability of SWOT analysis (Chang and Huang, 2005). The complete calculation of SWOT – AHP analysis in this research is provided in Appendix C and discussed in detail in this chapter.

7.2 SWOT-AHP Analysis: Perspective of Global Industry

Strength category: As set out in Figure 7-1, on economic value criteria, the most important factor was ‘more simplicity’ of local weight value 0.203. It was then followed by ‘less scaffolding and formwork’ (local weight = 0.191), ‘work in parallel’ (local weight = 0.191), ‘less labor required’ (local weight = 0.180), ‘more success on meeting quality specifications’ (local weight = 0.158), and ‘smaller on-site area and staging space required’ (local weight = 0.094). On ecological performance criteria, both factors of ‘efficiency material usage’ and ‘cleaner construction site’ had the same level of importance. Meanwhile on technical quality criteria, ‘highly durable building’ factor was slightly more important (local weight = 0.569) than ‘compensation for earthquake reduction factor’ (local weight = 0.431).

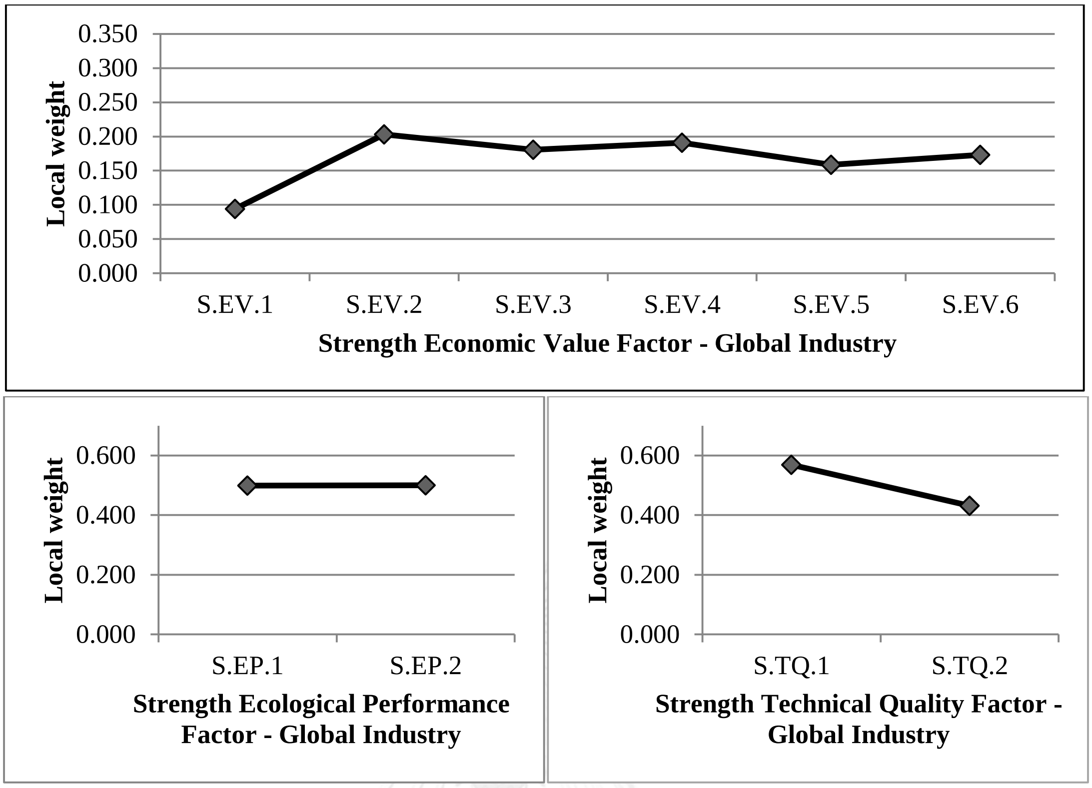


Figure 7-1.Global industry perception of factors under strength sustainability criteria

Weakness category: As set out in Figure 7-2, on economic value criteria, 'higher initial investments' was the most important factor of the local weight value 0.309, followed by 'heavy equipment required' (local weight = 0.268)', 'licensing fees' (local weight= 0.158), 'higher transportation costs' (local weight = 0.155), and 'repetitious designs' (local weight = 0.110). Meanwhile, on technical quality criteria, the most important factor was 'greater difficulties in making changes' (local weight = 0.428), followed by 'more complex connection designs' (local weight = 0.308), and 'greater loading difficulties for big components or long spans' (local weight = 0.264).

Opportunity category: As set out in Figure 7-3, the factors under implementation and enforcement criteria were dominating the opportunity of precast concrete implementation. The most important factor was 'higher needs of industrialization' (local weight = 0.232). It was followed by 'IAPPI facilitation of developing precast concrete systems (local weight = 0.225), 'Indonesian National Standard support' (local weight = 0.217), 'ministerial regulation support' (local weight = 0.183), and 'available routine training by IAPPI' (local weight = 0.142).

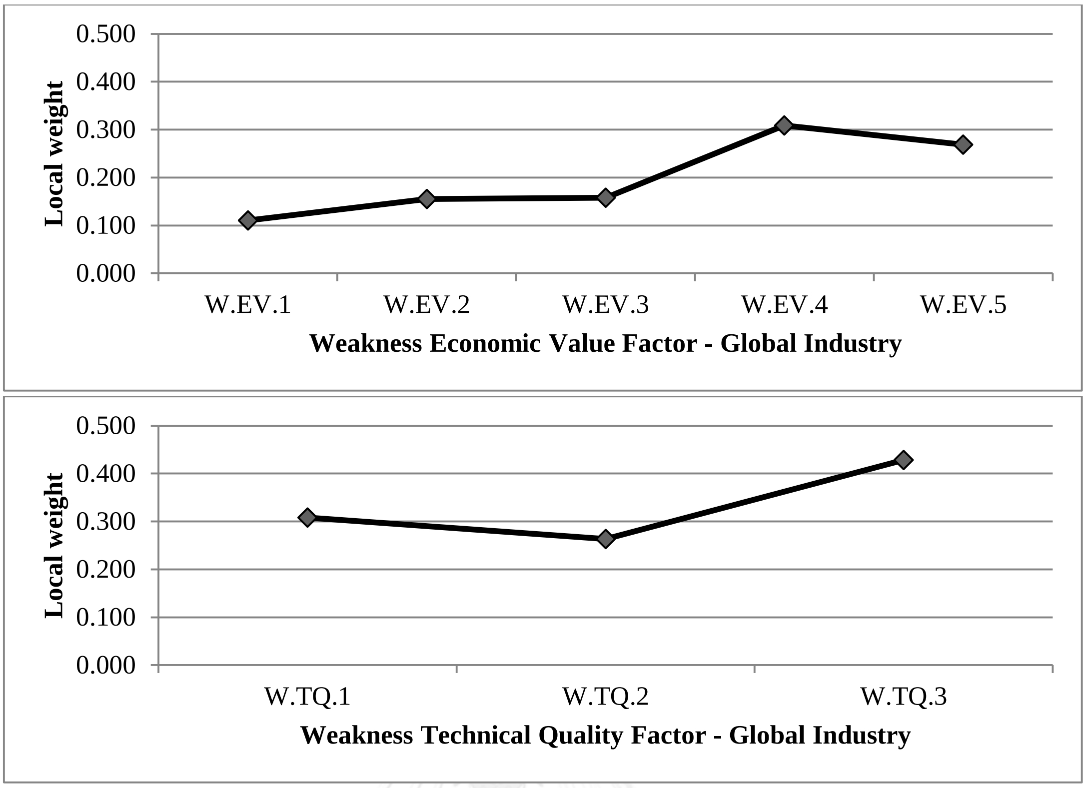


Figure 7-2.Global industry perception of factors under weakness sustainability criteria

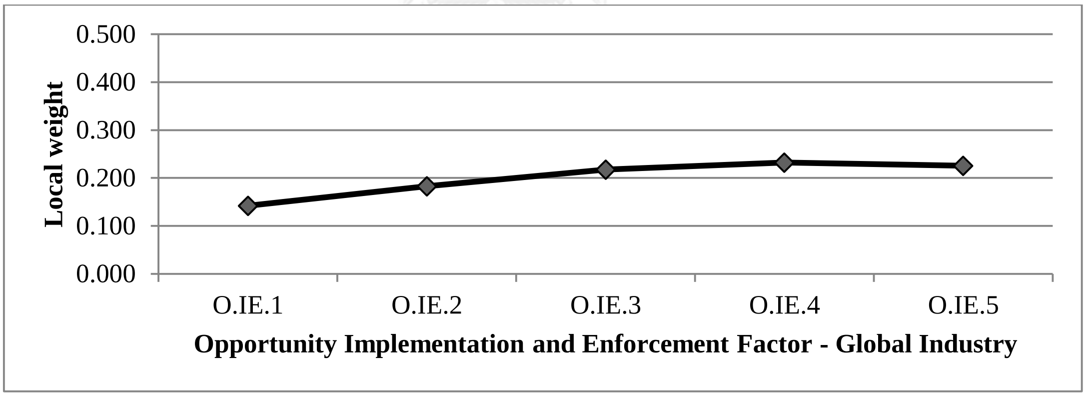


Figure 7-3.Global industry perception of factors under opportunity sustainability criteria

Threat category: As set out in Figure 7-4, on social equity and culture criteria, the most important factor was ‘shortage of expertise and skilled labor’ (local weight = 0.314), followed by ‘limited public awareness’ (local weight = 0.251), ‘development centralized in Java Island’ (local weight = 0.243), and ‘foreman-handyman culture difficult to change’ (local weight = 0.192). On the other hand, ‘lack of integrated standardization’ (local weight = 0.405) was the most important factor under implementation and enforcement criteria. It was followed by ‘road and bridge restrictions' (local weight = 0.306), and 'lack of government incentives, directives and promotion' (local weight = 0.289).

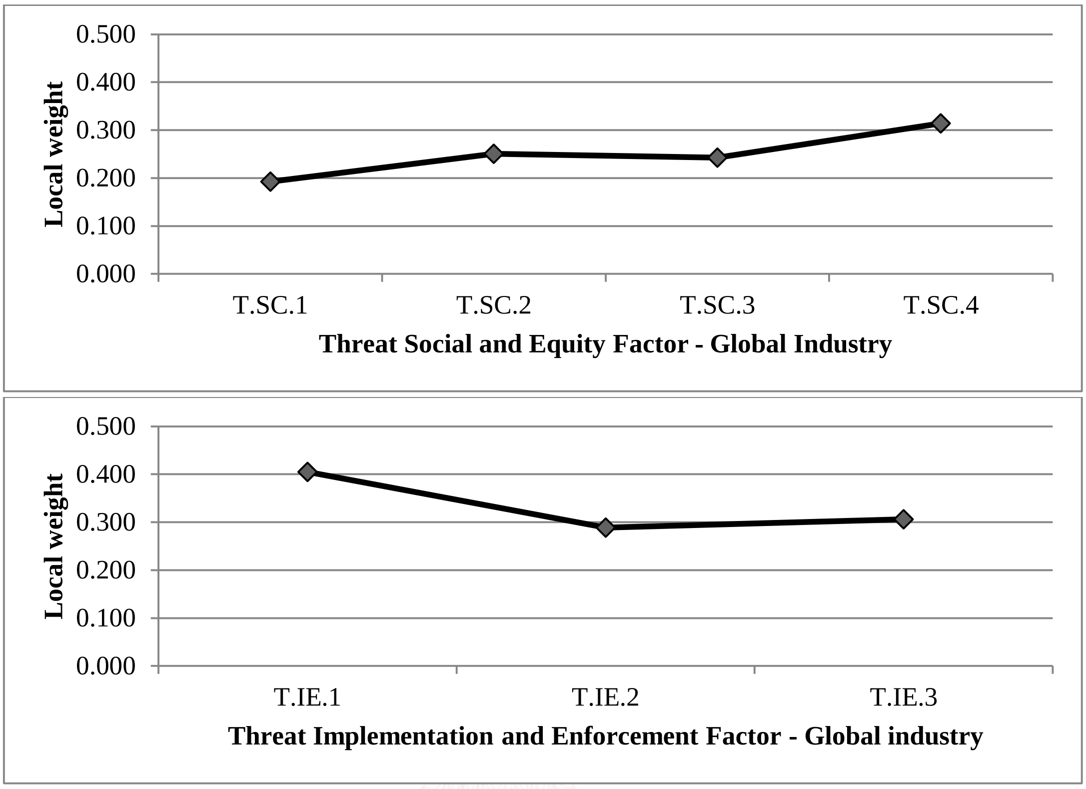


Figure 7-4.Global industry perception of factors under threat sustainability criteria

7.3 SWOT-AHP Analysis: Perspective of Government

Strength category: as set out in Figure 7-5, on economic value criteria, the most important factor was 'more simplicity' of local weight value 0.316. The value was considered to be very important because the gap to the next most important factor value was quite far (0.174), while the others five factors had gap among them on average of 0.004. The government as owner must have concerned to the simplicity of project because they need efficiency in coordinating and supervising a large number of projects. The next factor was 'work in parallel' (local weight = 0.143), followed by 'less labor required' (local weight = 0.142), 'less scaffolding and formwork' (local weight = 0.141), 'smaller on-site area and staging space required' (local weight = 0.135), and 'more success on meeting quality specifications' (local weight = 0.123). On ecological performance criteria, 'efficiency material usage' (local weight = 0.561) was slightly more important than 'cleaner construction site' (local weight = 0.439).

Meanwhile on technical quality criteria, both factors of ‘highly durable building’ and ‘compensation for earthquake reduction factor’ had the same level of importance.

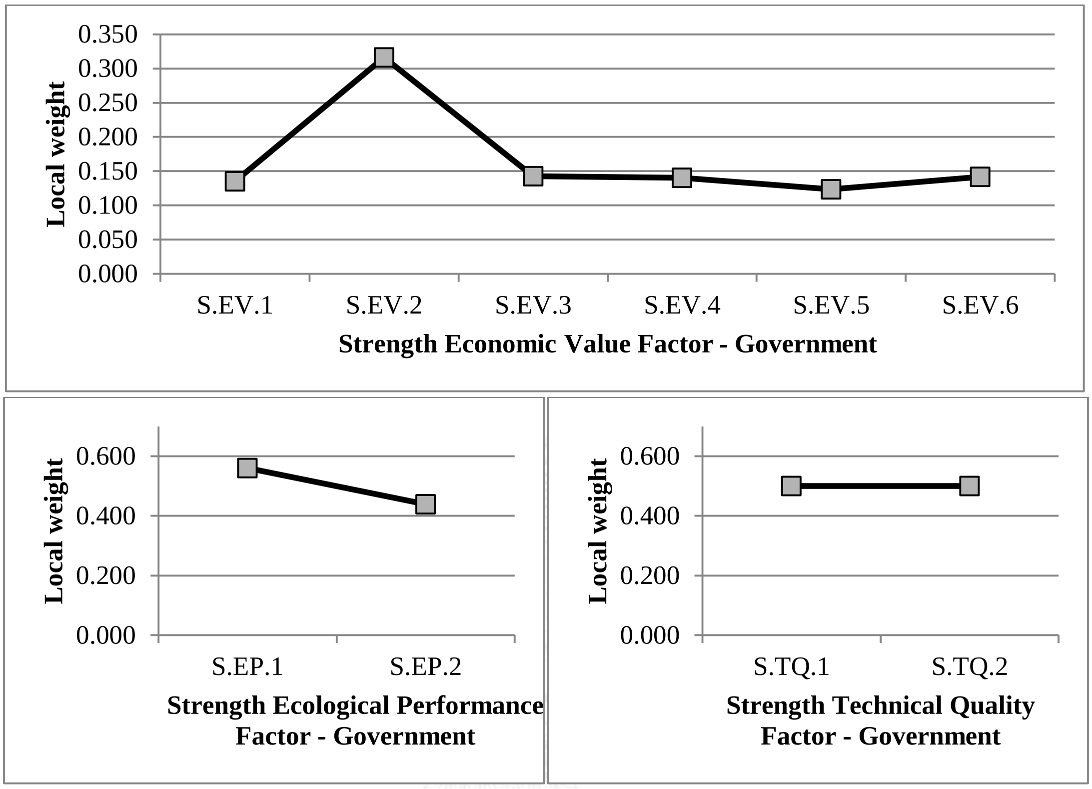


Figure 7-5.Government perception of factors under strength sustainability criteria

Weakness category: As set out in Figure 7-6, on economic value criteria, ‘licensing fees’ was the most important factor of the local weight value 0.312, and this was also considered to be very important, because the gap to the next important factor was far of 0.122 as compared to the average gap of four others (0.019). As the owner of public project, the government has responsibility to involve the public participation. It was then responded by the precaster to obtain the license of their precast product innovation. Therefore, the government must improve their knowledge on precast technology in order to be able to select the best precaster among many others. The next factors ‘heavy important required and repetitious design have the same level of importance (local weight = 0.190). These are followed by ‘higher initial investment’ (local weight = 0.174), and ‘higher transportation cost’ (local weight = 0.134). Meanwhile, on technical quality criteria, the most important factor was ‘more complex connection designs’ (local weight = 0.410). It was in accordance to the first rank factor on economic value of ‘licensing fees’, because both factors had strong relationship. Precast concrete system is licensed for its innovation in connection design system. The government may experience difficulties in supervising number of dissimilarity products among registered connection design. The next factor in technical quality was 'greater difficulties in making changes' (local weight = 0.319), followed by 'greater loading difficulties for big components or long spans' (local weight = 0.271).

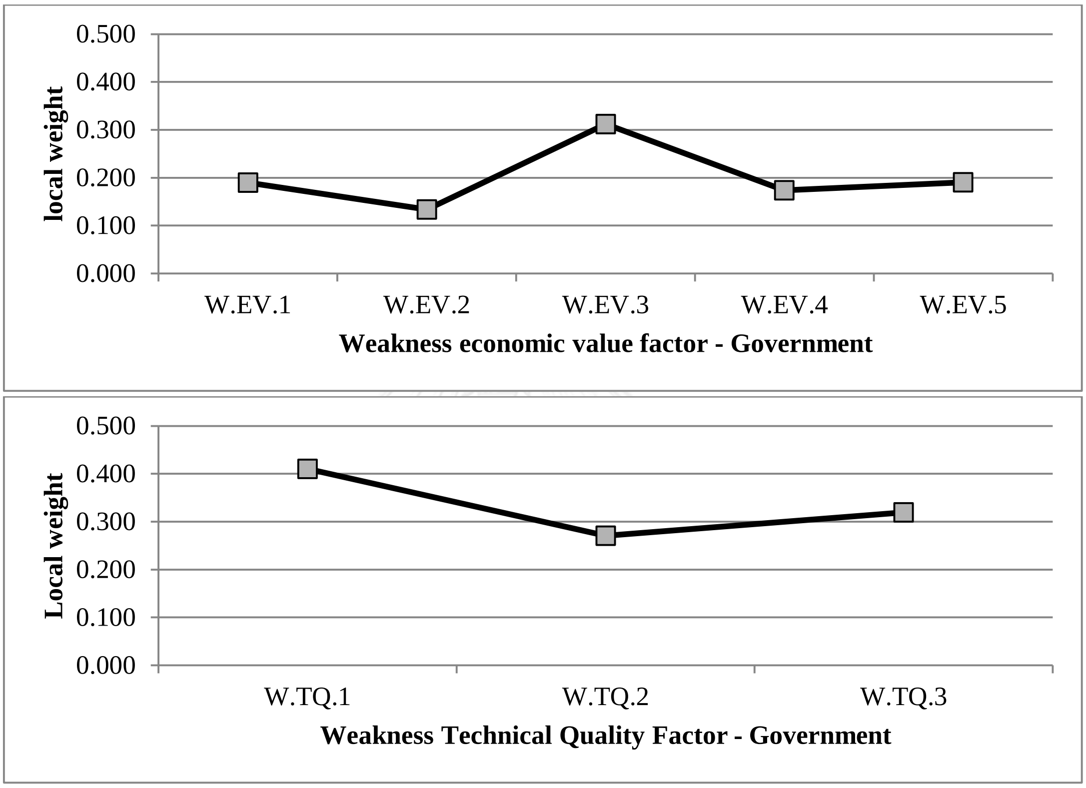


Figure 7-6.Government perception of factors under weakness sustainability criteria

Opportunity category: As set out in Figure 7-7, the factors under implementation and enforcement criteria were dominating the opportunity of precast concrete implementation. Among them, the most important factor was 'Indonesian National Standard support' (local weight = 0.235), followed by 'IAPPI facilitation of developing precast concrete systems (local weight = 0.224), by 'ministerial regulation support' (local weight = 0.194), 'available routine training by IAPPI' (local weight = 0.183), and 'higher needs of industrialization' (local weight = 0.164).

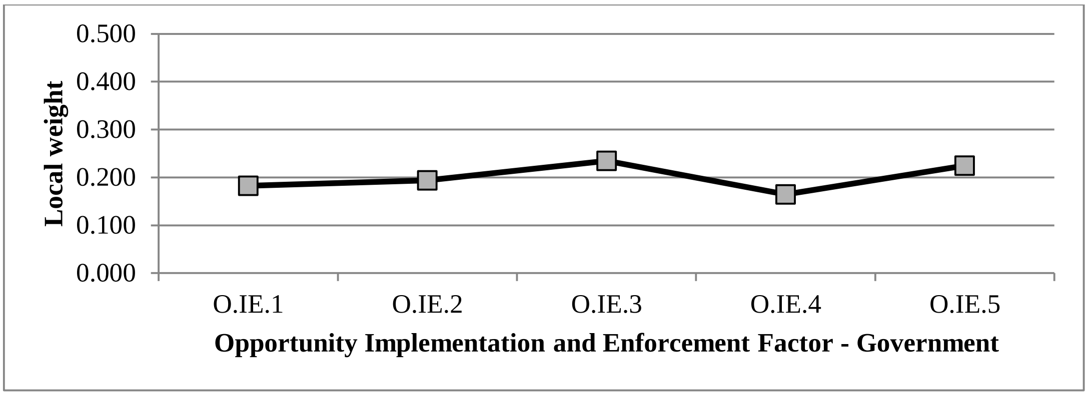
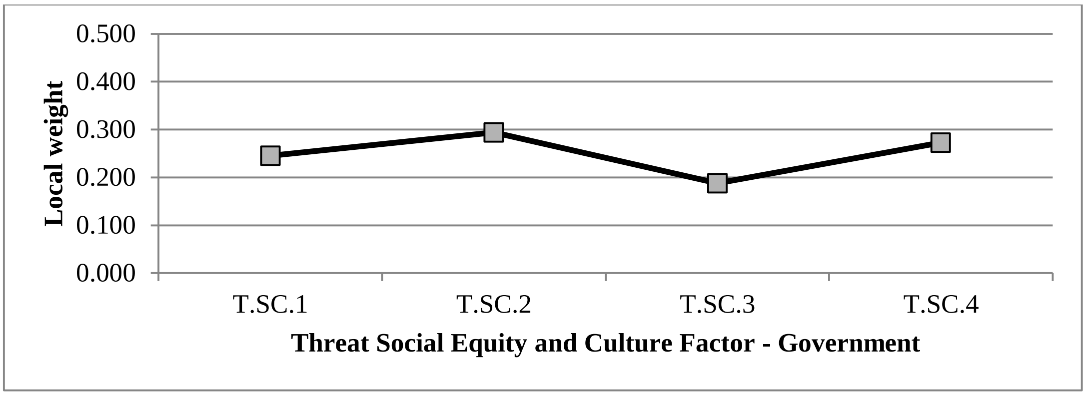


Figure 7-7.Government perception of factors under weakness sustainability criteria

Threat category: As set out in Figure 7-8, on social equity and culture criteria, the most important factor was 'limited public awareness' (local weight = 0.294), followed by 'shortage of expertise and skilled labor' (local weight = 0.273), 'foreman-handyman culture difficult to change' (local weight = 0.246), and 'development centralized in Java Island' (local weight = 0.188). 'Development centralized in Java Island' may have the least level of importance in Government opinion, because the Government has many projects all around Indonesia and experiences good performance. On the other hand, 'lack of integrated standardization' (local weight = 0.449) was the most important factor under implementation and enforcement criteria. It was followed by 'road and bridge restrictions' (local weight = 0.352), and 'lack of government incentives, directives and promotion' (local weight = 0.199).



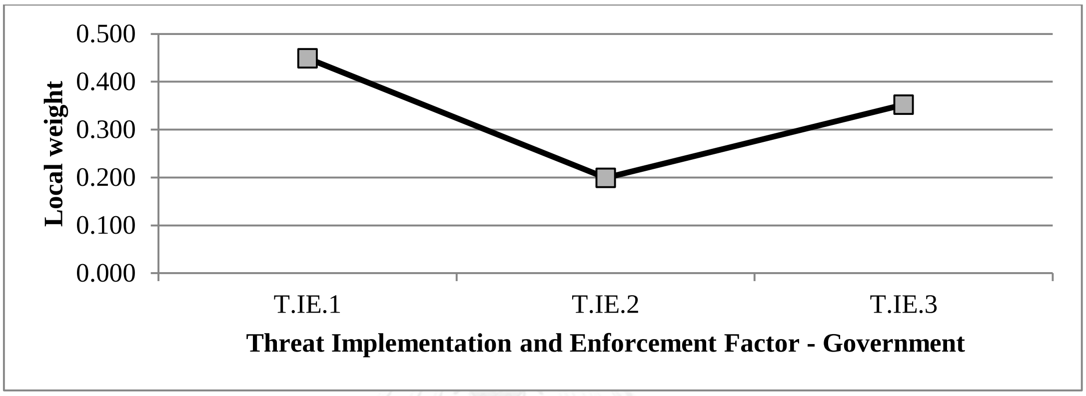


Figure 7-8.Government perception of factors under weakness sustainability criteria

7.4 SWOT-AHP Analysis: Perspective of Manufacturer

Strength category: As set out in Figure 7-9, on economic value criteria, the most important factor was 'more simplicity' of local weight value 0.244. The next factor was 'work in parallel' (local weight = 0.209), followed by 'less scaffolding and formwork' (local weight = 0.166), 'more success on meeting quality specifications' (local weight = 0.159), 'less labor required' (local weight = 0.144), and 'smaller on-site area and staging space required' (local weight = 0.135). On ecological performance criteria, 'cleaner construction site' (local weight = 0.610) was more important than 'more efficient material usage' (local weight = 0.390). Meanwhile on technical quality criteria, 'highly durable building' (local weight = 0.540) was slightly more important than 'compensation for earthquake reduction factor' (local weight = 0.460).

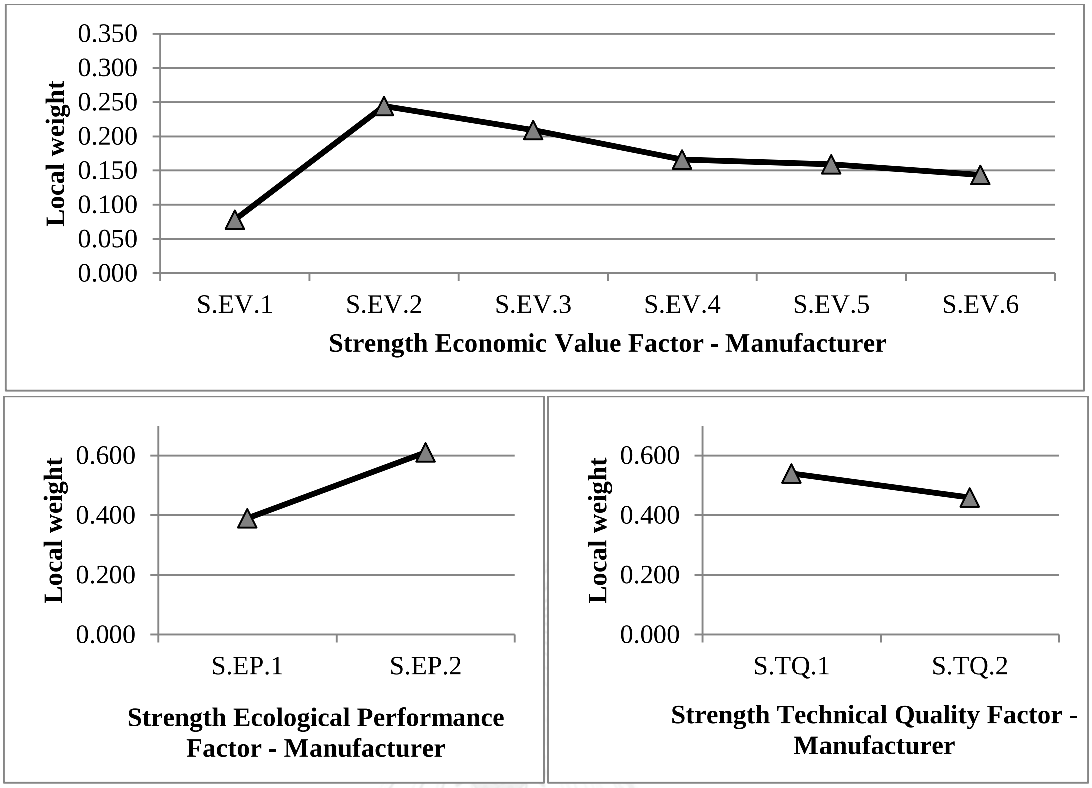
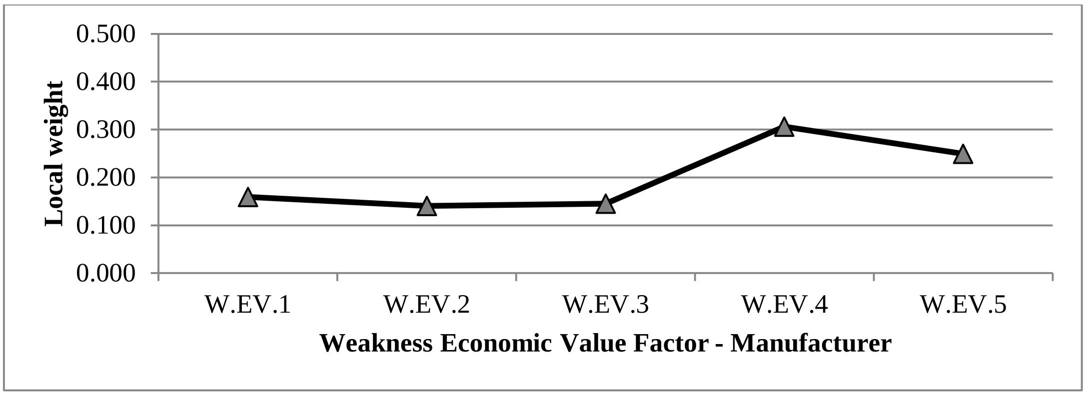


Figure 7-9.Manufacturer perception of factors under strength sustainability criteria

Weakness category: As set out in Figure 7-10, on economic value criteria, 'higher transportation cost' was the most important factor of the local weight value 0.306. It was no surprise if this factor gets the most attention from manufacturer since they were the one who invents the technology and sets the factory for the first time. The next factor was 'heavy important required' (local weight = 0.250), followed by 'repetitious design' (local weight = 0.159), 'licensing fees' (local weight = 0.145), and 'higher transportation cost' (local weight = 0.140). Meanwhile, on technical quality criteria, the most important factor was 'greater difficulties in making changes' (local weight = 0.499). The next factor in technical quality was 'more complex connection designs' (local weight = 0.333), followed by 'greater loading difficulties for big components or long spans' (local weight = 0.168).



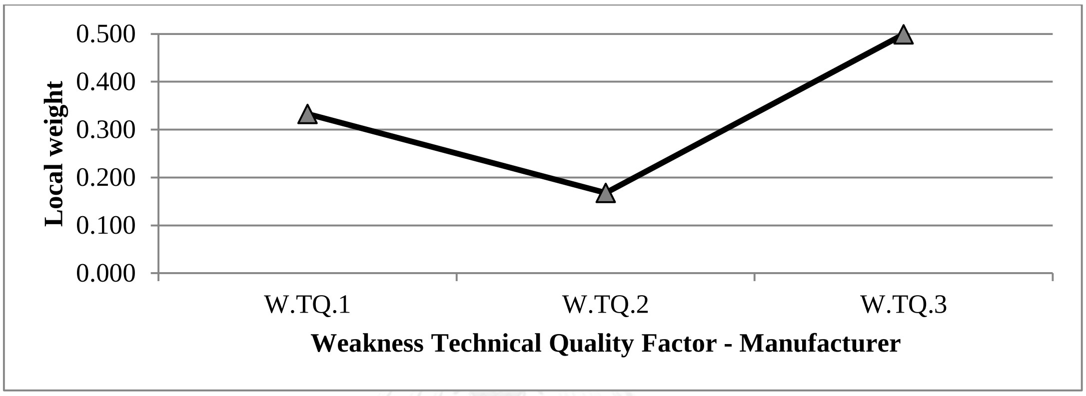


Figure 7-10.Manufacturer perception of factors under weakness sustainability criteria

Opportunity category: As set out in Figure 7-11, the factors under implementation and enforcement criteria were dominating the opportunity of precast concrete implementation. Among them, the most important factor was 'Indonesian National Standard support' (local weight = 0.267), followed by 'ministerial regulation support' (local weight = 0.218), 'higher needs of industrialization' (local weight = 0.192), 'IAPPI facilitation of developing precast concrete systems (local weight = 0.177), and 'available routine training by IAPPI' (local weight = 0.146).

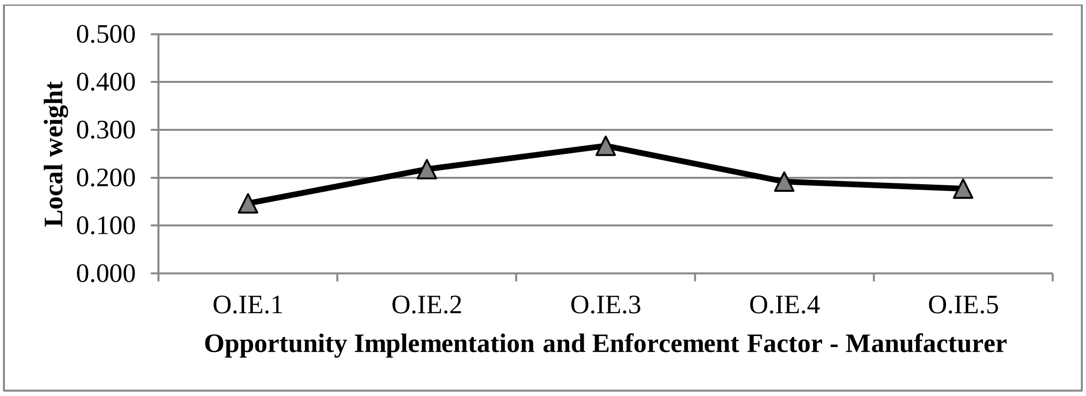
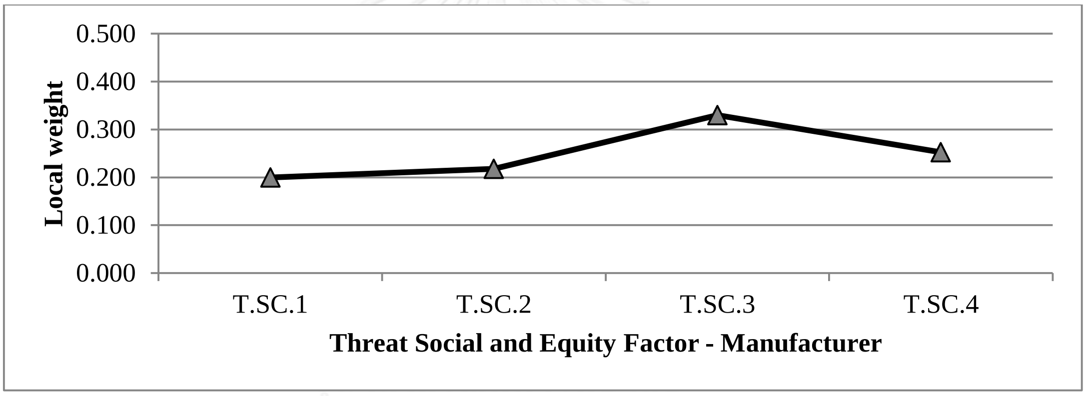


Figure 7-11.Manufacturer perception of factors under opportunity sustainability criteria

Threat category: As set out in Figure 7-12, on social equity and culture criteria, the most important factor was 'development centralized in Java Island' (local weight = 0.330). When set-up a new factory in a region, manufacturer should consider the market or production activity to achieve reasonable profit business. Therefore, the centralized development in a region is a problem to the manufacturers to expand their factory to other less development regions. The next factor was 'shortage of expertise and skilled labor' (local weight = 0.252), followed by 'limited public awareness' (local weight = 0.218), and 'foreman-handyman culture difficult to change' (local weight = 0.200). On the other hand, 'lack of integrated standardization' (local weight = 0.412) was the most important factor under implementation and enforcement criteria. It was followed by 'lack of government incentives, directives and promotion' (local weight = 0.345) and 'road and bridge restrictions' (local weight = 0.243).



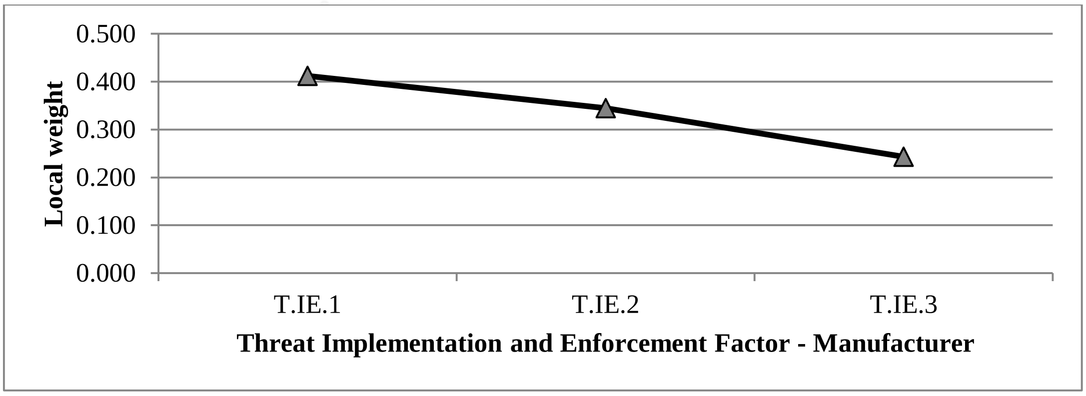


Figure 7-12.Manufacturer perception of factors under threat sustainability criteria

7.5 SWOT-AHP Analysis: Perspective of Contractor

Strength category: As set out in Figure 7-13, on economic value criteria, the most important factor was 'less scaffolding and formwork' (local weight = 0.318).

This is because the contractor is the first party to apply scaffolding and formwork on-site construction project. The next factor was 'less labor required' (local weight = 0.225), followed by 'work in parallel' (local weight = 0.178), 'more success on meeting quality specifications' (local weight = 0.123), 'more simplicity' (local weight = 0.090), and 'smaller on-site area and staging space required' (local weight = 0.067). On ecological performance criteria, 'more efficient material usage' (local weight = 0.530) was slightly more important than 'cleaner construction site' (local weight = 0.470). Meanwhile on technical quality criteria, both factors 'highly durable building' and 'compensation for earthquake reduction factor' had same level of importance.

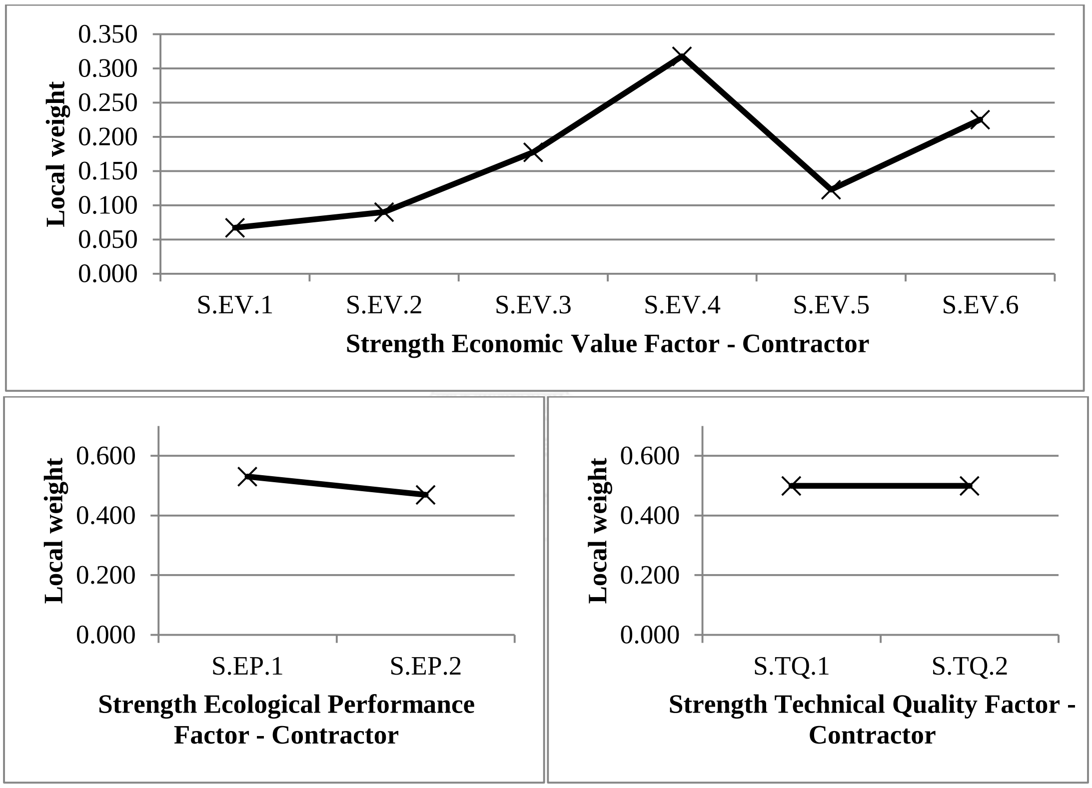


Figure 7-13.Contractor perception of factors under strength sustainability criteria

Weakness category: As set out in Figure 7-14, on economic value criteria, 'heavy important required' was the most important factor of the local weight value 0.420. It was no surprise that this factor got the most attention from Contractor since they were the one who should provide the heavy equipment on-site construction which was most of them do not have their own equipment. Accordingly, they have to rent equipment. The next factor was 'higher initial investments' (local weight = 0.295), followed by 'licensing fees' (local weight = 0.117), 'higher transportation cost' (local weight = 0.106), and ‘repetitious design’ (local weight = 0.062). Meanwhile, on technical quality criteria, the most important factor was ‘greater difficulties in making changes’ (local weight = 0.482). The next factor in technical quality was ‘greater loading difficulties for big components or long spans’ (local weight = 0.304), followed by ‘more complex connection designs’ (local weight = 0.215).

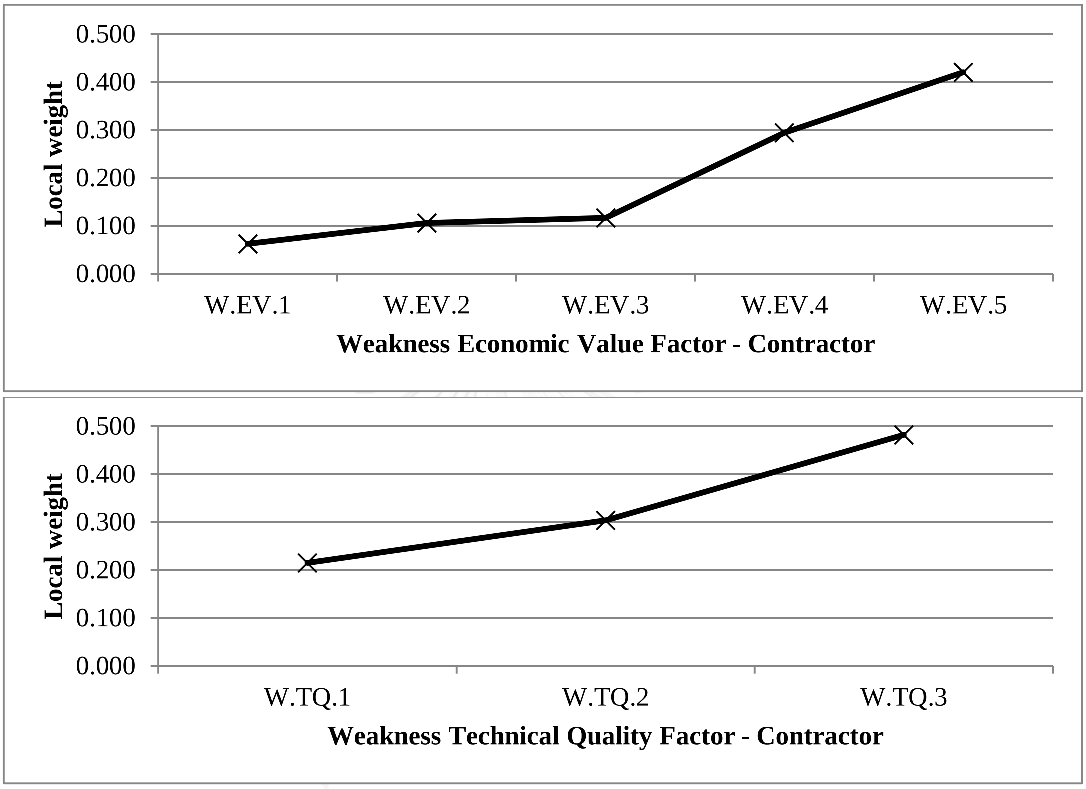


Figure 7-14.Contractor perception of factors under weakness sustainability criteria

Opportunity category: As set out in Figure 7-15, the factors under implementation and enforcement criteria were dominating the opportunity of precast concrete implementation. Among them, the most important factor was ‘higher needs of industrialization’ (local weight = 0.387). The higher needs of industrialization lead to increasing number of construction projects. The opportunity of the contractor to get the job is increasing as well. The next factor was ‘IAPPI facilitation of developing precast concrete systems (local weight = 0.207), followed by ‘ministerial regulation support’ (local weight = 0.201), ‘Indonesian National Standard support’ (local weight = 0.129), and ‘available routine training by IAPPI’ (local weight = 0.077).

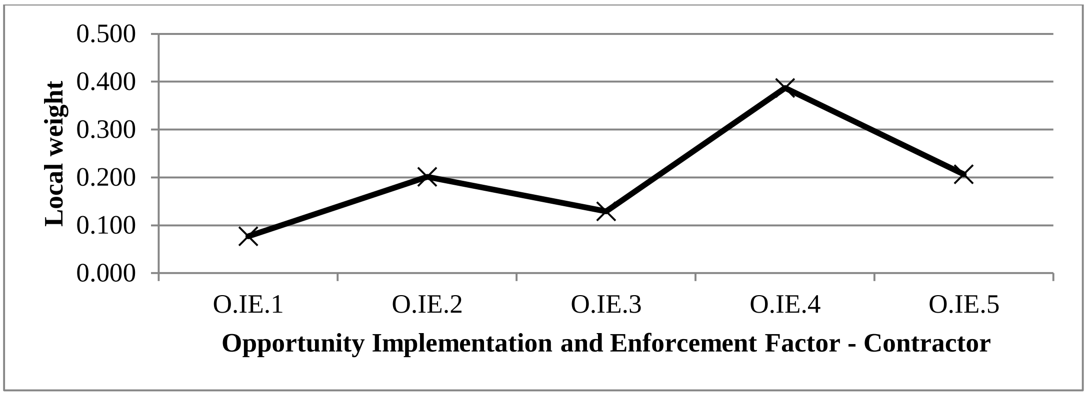


Figure 7-15.Contractor perception of factors under opportunity sustainability criteria

Threat category: As set out in Figure 7-16, on social equity and culture criteria, the most important factor was 'shortage of expertise and skilled labor' (local weight = 0.446), followed by 'limited public awareness' (local weight = 0.251), 'foreman-handyman culture difficult to change' (local weight = 0.162), and 'development centralized in Java Island' (local weight = 0.141). On the other hand, 'lack of integrated standardization' (local weight = 0.360) was the most important factor under implementation and enforcement criteria. It was followed by 'road and bridge restrictions' (local weight = 0.327), and 'lack of government incentives, directives and promotion' (local weight = 0.313).

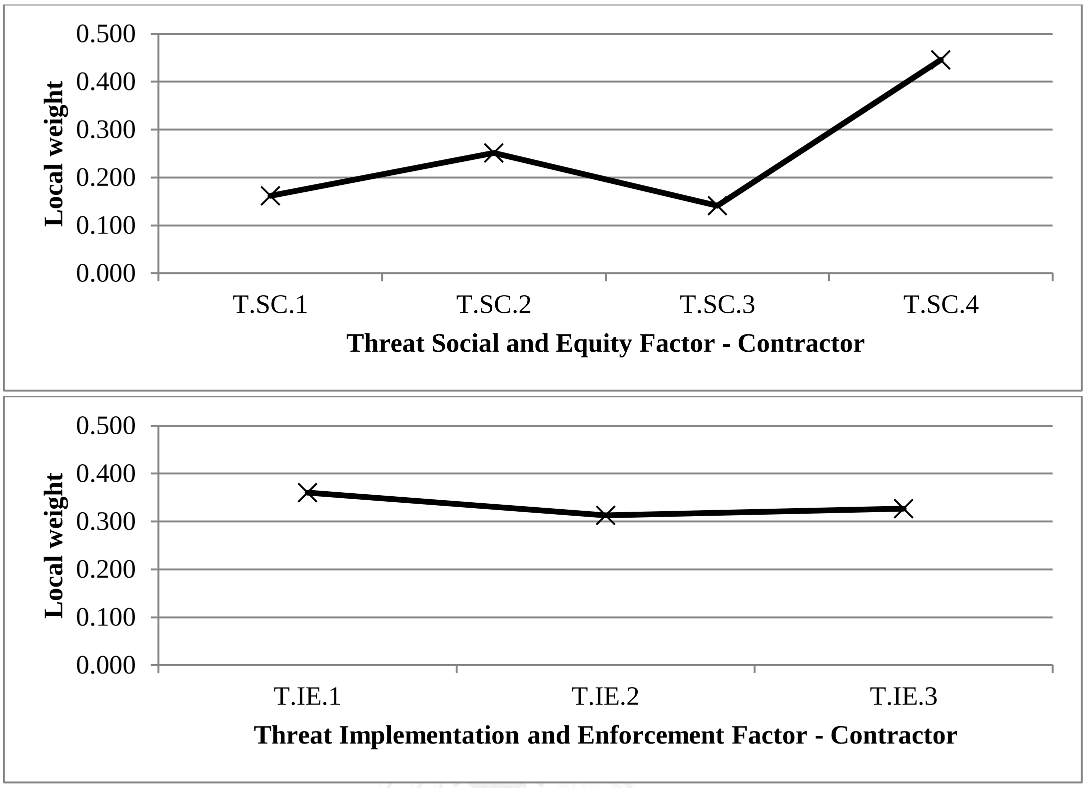


Figure 7-16.Contractor perception of factors under threat sustainability criteria

7.6 SWOT-AHP Analysis: Perspective of Consultant/Designer

Strength category: As set out in Figure 7-17, on economic value criteria, the most important factor was 'more success on meeting quality specifications' of local weight value 0.207. It was no surprise that this factor got the most attention because the consultant/designer was the one who play role of supervising and designing. The next factor was 'less scaffolding and formwork' (local weight = 0.204) followed by 'less labor required' (local weight = 0.195), 'work in parallel' (local weight = 0.181), 'more simplicity' (local weight = 0.137), and 'smaller on-site area and staging space required' (local weight = 0.075). On ecological performance criteria, 'more efficient material usage' (local weight = 0.534) was slightly more important than 'cleaner construction site' (local weight = 0.466). Meanwhile on technical quality criteria, 'highly durable building' (local weight = 0.698) was more important than 'compensation for earthquake reduction factor' (local weight = 0.302).

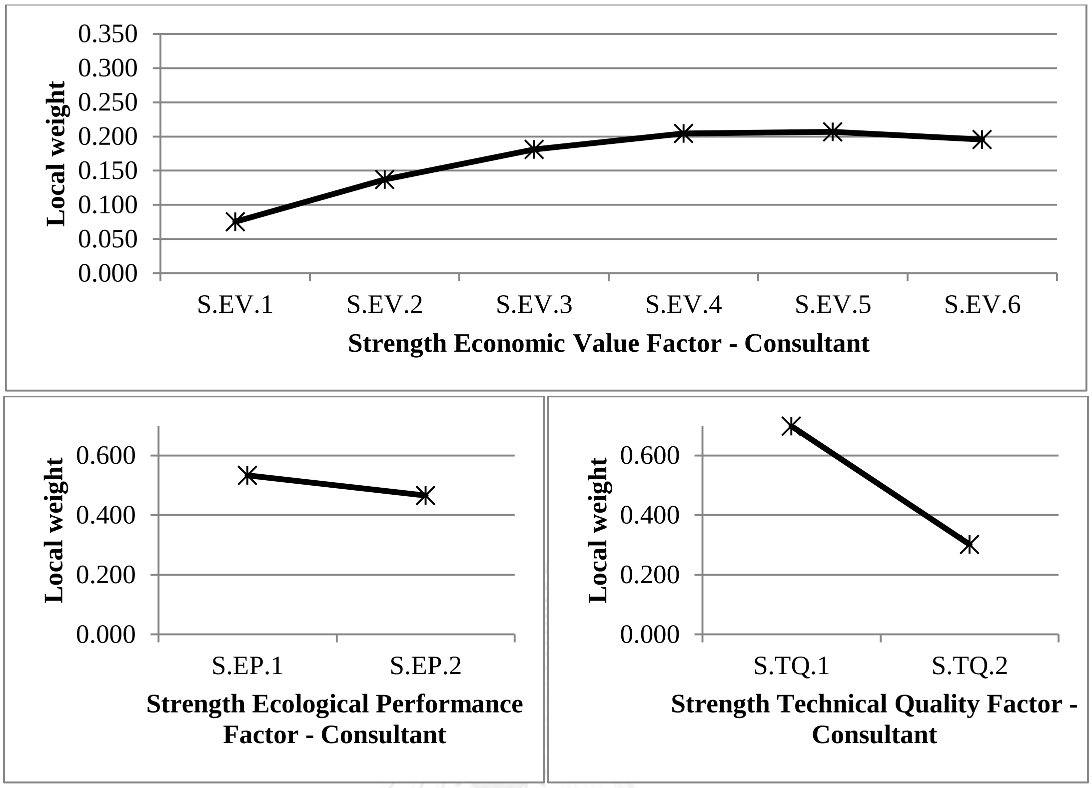


Figure 7-17.Consultant/designer perception of factors under strength sustainability criteria

Weakness category: As set out in Figure 7-18, on economic value criteria, ‘higher initial investments’ was the most important factor of the local weight value 0.411. The next factor was ‘heavy important required’ (local weight = 0.213), followed by ‘higher transportation cost’ (local weight = 0.205), ‘licensing fees’ (local weight = 0.101), and ‘repetitious design’ (local weight = 0.069). Meanwhile, on technical quality criteria, the most important factor was ‘greater difficulties in making changes’ (local weight = 0.393). The next factor in technical quality was ‘greater loading difficulties for big components or long spans’ (local weight = 0.327) followed by ‘more complex connection designs’ (local weight = 0.280).

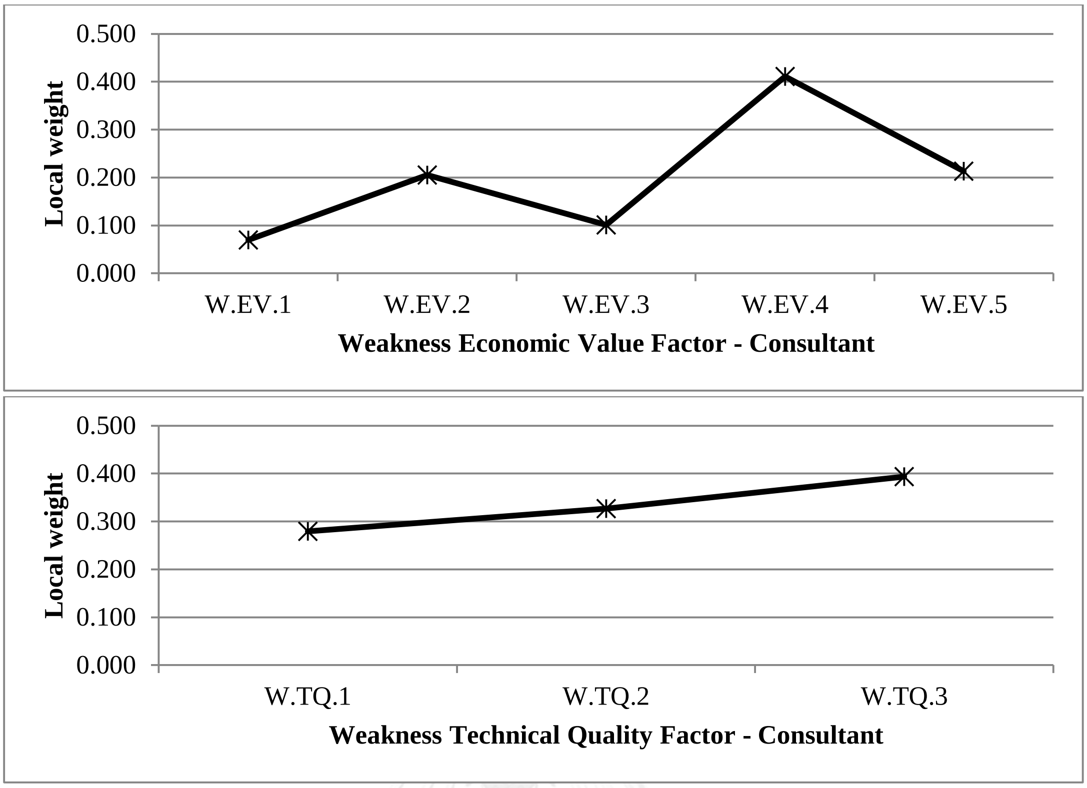


Figure 7-18.Consultant/designer perception of factors under weakness sustainability criteria

Opportunity category: As set out in Figure 7-19, the factors under implementation and enforcement criteria were dominating the opportunity of precast concrete implementation. Among them, the most important factor was ‘IAPPI facilitation of developing precast concrete systems (local weight = 0.268), followed by ‘higher needs of industrialization’ (local weight = 0.265), ‘Indonesian National Standard support’ (local weight = 0.198), ‘ministerial regulation support’ (local weight = 0.137), and ‘available routine training by IAPPI’ (local weight = 0.132).

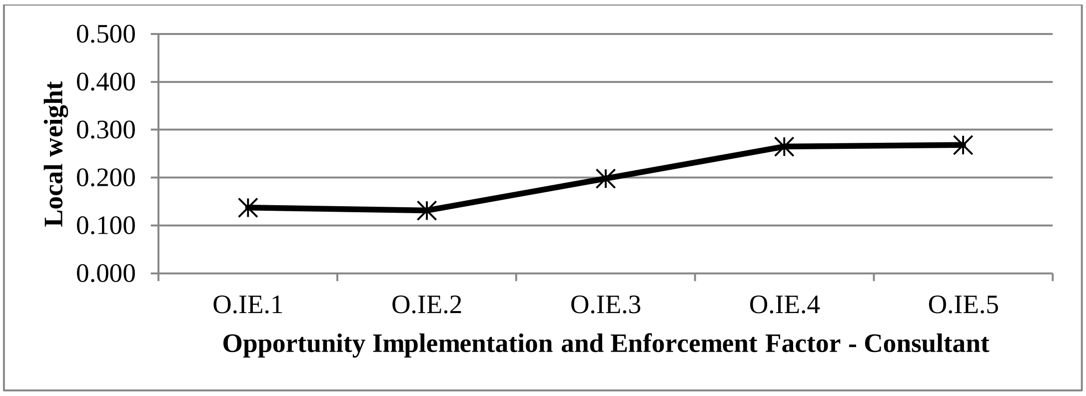


Figure 7-19.Consultant/designer perception of factors under opportunity sustainability criteria

Threat category: As set out in Figure 7-20, on social equity and culture criteria, the most important factor was ‘development centralized in Java Island’ (local weight = 0.328). The next factor was ‘shortage of expertise and skilled labor’ (local weight = 0.309), followed by ‘limited public awareness’ (local weight = 0.217), and ‘foreman-handyman culture difficult to change’ (local weight = 0.145). On the other hand, ‘lack of integrated standardization’ (local weight = 0.376) was the most important factor under implementation and enforcement criteria. It was followed by ‘lack of government incentives, directives and promotion’ (local weight = 0.316) and ‘road and bridge restrictions’ (local weight = 0.308).

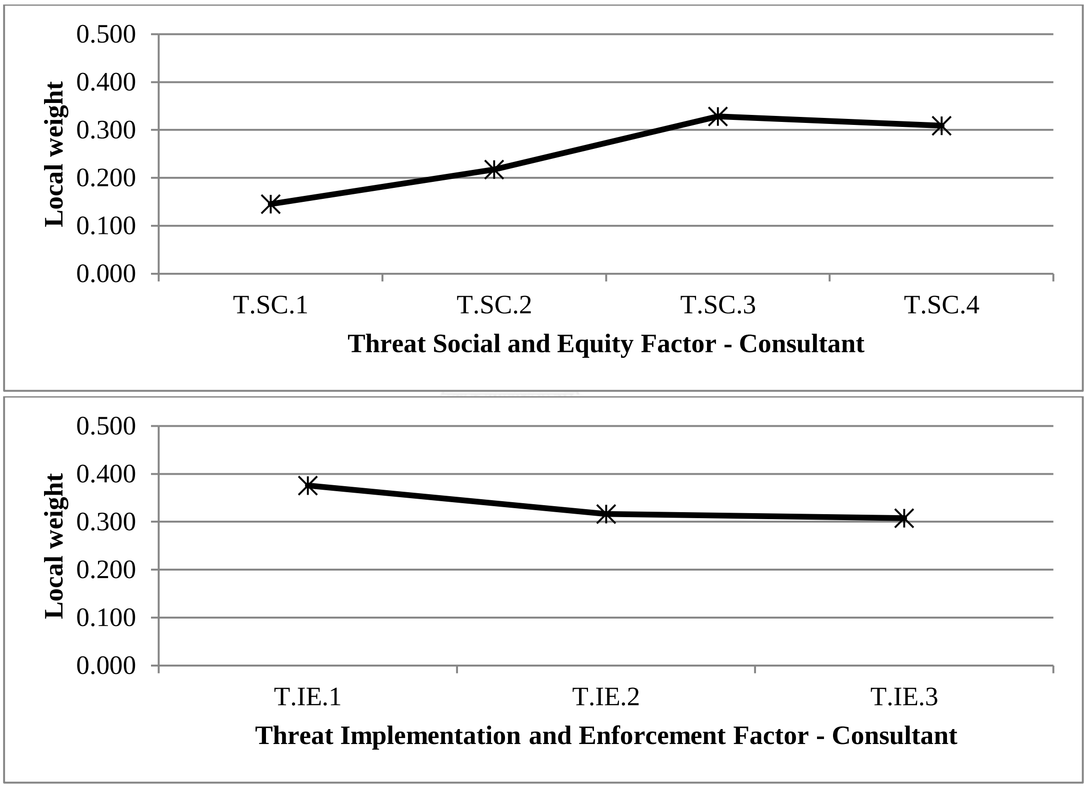


Figure 7-20.Consultant/designer perception of factors under threat sustainability criteria

7.7 Perception Map of Precast Concrete Implementation in Indonesia

SWOT analysis of precast concrete sustainable implementation considered five pillar sustainability criteria, namely, economic value (EV), ecological performance (EP), social equity and culture (Institute), technical quality (TQ), and implementation and enforcement (IE). The SWOT factors were then derived from the sustainability criteria. However, there was only one sustainable criterion exist in all

SWOT category that was technical quality. In detail, under the strength category, there were four sustainability criteria: economic value, ecological performance, social equity and culture, and technical quality. The weakness category contained economic value and technical quality. Under opportunity, there were technical quality and implementation and enforcement, while social equity and culture, technical quality, and implementation and enforcement came under the threat category.

The results as set out in Figure 7-21, indicated that the global industry perceive technical quality as the most important criteria under all SWOT category. Precast concrete itself was a product of technology innovation in construction industry. However, technology innovation is dynamic in order to meet the market demand. As the work conducted by Adner and Levinthal (2001), for technology life cycle showed that innovation was guided by a drive to meet market requirements in the early stages of technology's development. In the later stages of development, innovation is driven by competition among suppliers faced with "technologically satisfied" consumers, after market's price and performance requirements are met.

The interesting fact from the result was that the manufacturer group had different opinion across the other stakeholder groups. The manufacturer group perceived economic value as the most important criteria under strength category. It was can be understood that the manufacturer was in the front row to run the precast concrete business. Therefore, the manufacturer should provide the competitive advantage of precast concrete load bearing wall product, which have better economic value with good technical quality. Another interesting fact also came from the difference of the manufacturer to perceive implementation and enforcement as the most important criteria under opportunity and threat category. The manufacturer put technical quality as the least important criteria for both external environmental variables. They may perceive without the support from the environment, no matter how well the product, it was not going to be successful in the market. Du Plessis (2007) contended technology by itself was useless, unless supported by processes for technology transfer and functioning institutions to facilitate the uptake of new technologies.

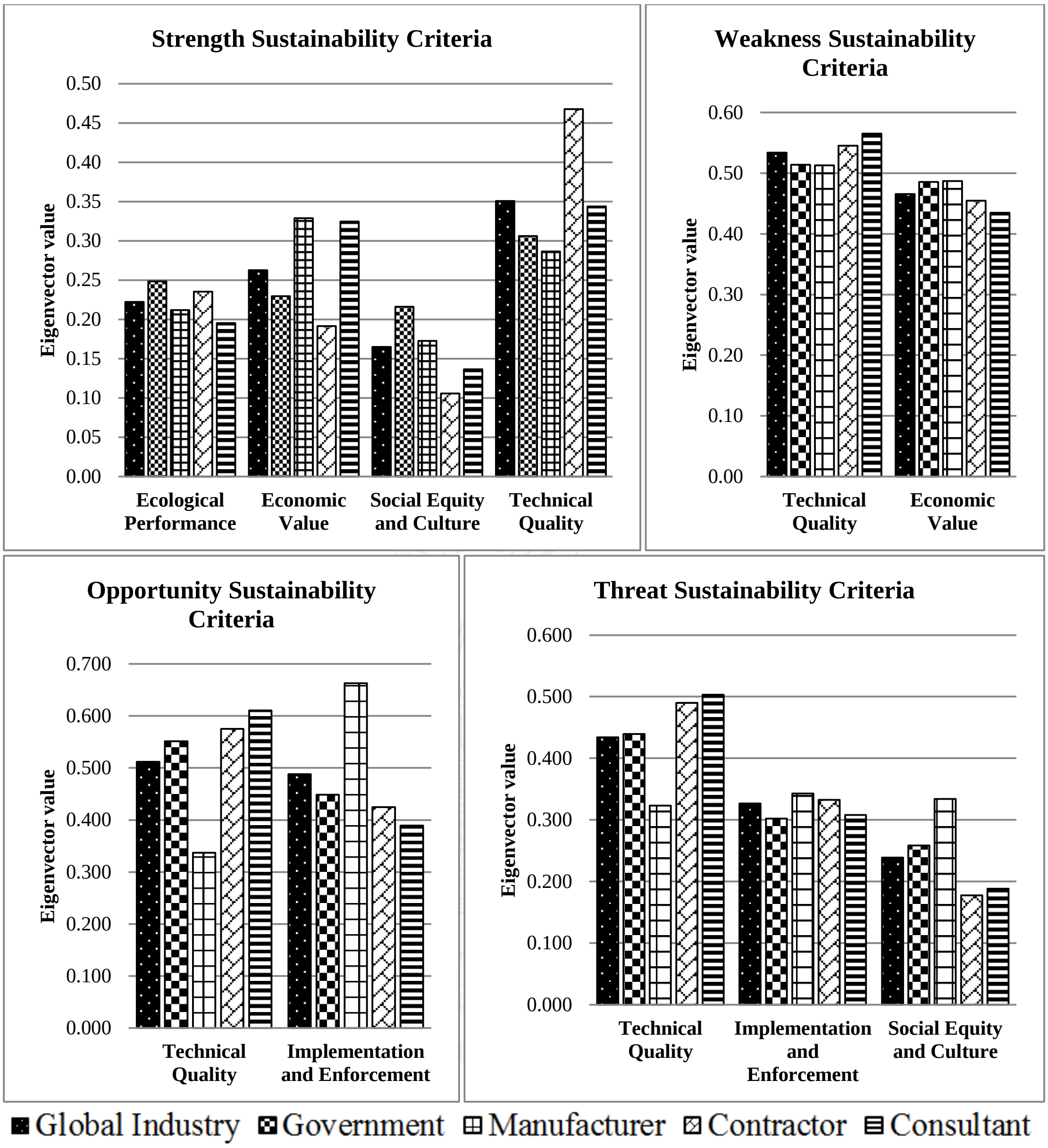


Figure 7-21.Importance level of sustainability criteria under SWOT category

The results as set out in Figure 7-22, illustrates the overall stakeholder groups perception of SWOT factors regarding sustainability criteria by multiplying sustainability criteria local weights by its factors local weights. It can be seen that the opinion across stakeholders groups were varied in determining weight importance of strategic factors.

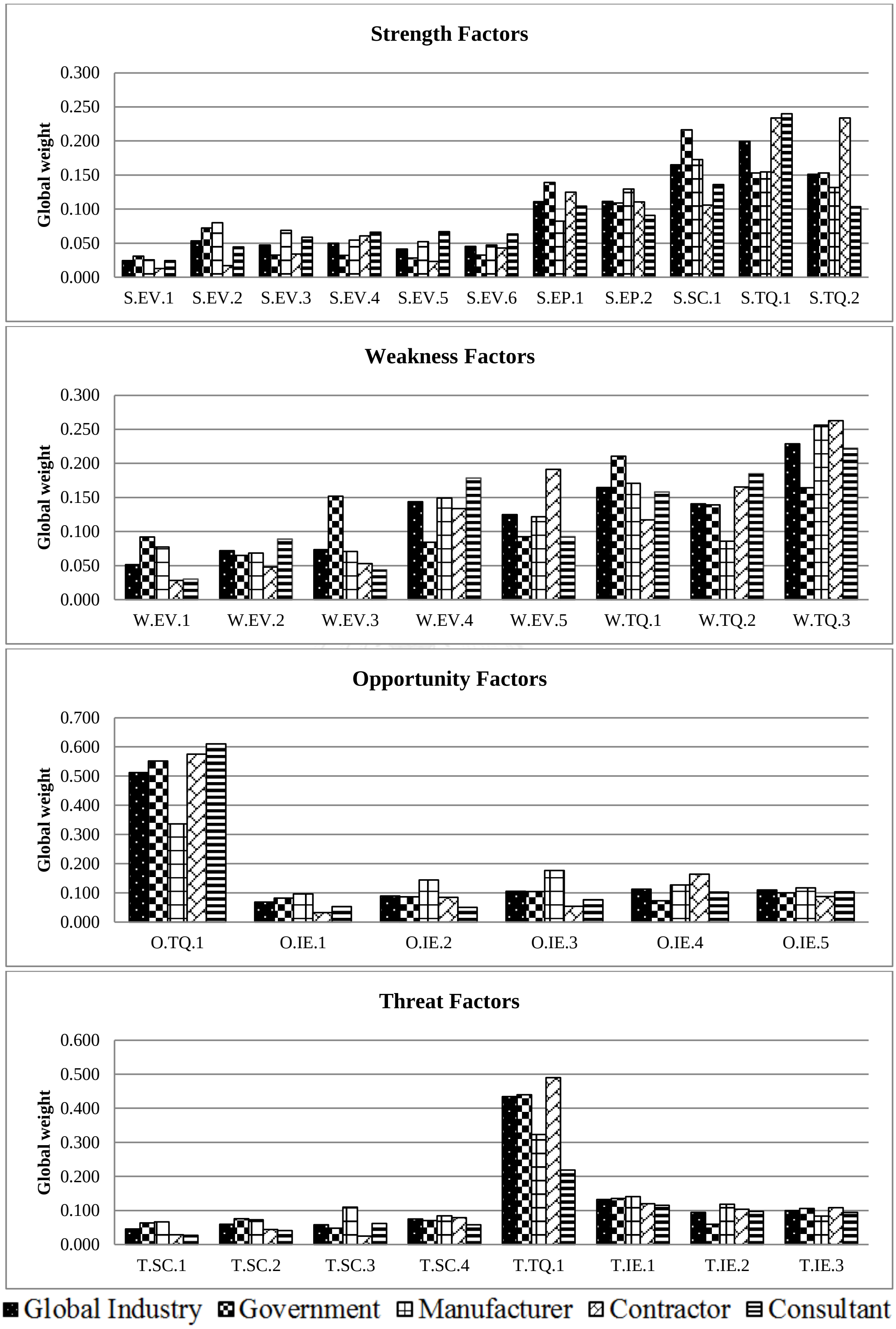


Figure 7-22.Stakeholder groups SWOT-AHP perception maps of precast concrete implementation

The results as set out in Table 7-1, showed the perception of the stakeholder groups of the three most important factors under SWOT category. Although, the ranking order was varied across stakeholder groups, the summary of three most important factors for global industry was in accordance to the factors that appeared most in stakeholder groups. Under strength category, the three most important factors were ‘more highly durable buildings’, ‘greater job security’, and ‘compensation for earthquake reduction’ factors, respectively. These factors were in accordance with the three most important factors across the stakeholder groups, although they had different orders. This applied to weakness, opportunity and category as well. Under weakness category, the three most important factors were, ‘greater difficulties in making changes during construction’, ‘more complex connection designs’, ‘higher initial investments’. Under opportunity category, the three most important factors were ‘availability of equipment’, ‘higher needs for industrialization’, and ‘IAPPI facilitation of developing precast concrete systems’. Under threat category, the three most important factors were ‘differences in quality and quantity of materials’, ‘lack of integrated standardization’ and ‘road and bridge restrictions’. The more complete calculation can be seen in Appendix C.

Table 7-1.The perception of the stakeholder groups of the three most important factors under SWOT category

No	All	Government	Manufacturer	Contractor	Consultant/Designer
Strength					
1	More highly durable buildings	Greater job security	Greater job security	More highly durable buildings	More highly durable buildings
2	Greater job security	More highly durable buildings	More highly durable buildings	Compensation for earthquake reduction factor	Compensation for earthquake reduction factor
3	Compensation for earthquake reduction factor	Compensation for earthquake reduction factor	Compensation for earthquake reduction factor	More efficient material usage	Greater job security
Weakness					
1	Greater difficulties in making changes during construction	More complex connection designs	Greater difficulties in making changes during construction	Greater difficulties in making changes during construction	Greater difficulties in making changes during construction
2	More complex connection designs	Greater difficulties in making changes during construction	More complex connection designs	Greater loading difficulties for big components or long spans	Higher initial investments
3	Higher initial investments	Licensing fees	Higher initial investments	Heavy equipment dependent	Greater loading difficulties for big components or long spans
Opportunity					
1	Availability of equipment	Availability of equipment	Availability of equipment	Availability of equipment	Availability of equipment
2	Higher needs for industrialization	Indonesian National Standard support	Indonesian National Standard support	Higher needs for industrialization	IAPPI facilitation of developing precast concrete systems
3	IAPPI facilitation of developing precast concrete systems	IAPPI facilitation of developing precast concrete systems	Ministerial regulation support	IAPPI facilitation of developing precast concrete systems	Higher needs for industrialization
Threat					
1	Differences in quality and quantity of materials	Differences in quality and quantity of materials	Differences in quality and quantity of materials	Differences in quality and quantity of materials	Differences in quality and quantity of materials
2	Lack of integrated standardization	Lack of integrated standardization	Lack of integrated standardization	Lack of integrated standardization	Lack of integrated standardization
3	Road and bridge restrictions	Road and bridge restrictions	Lack of government incentives, directives and promotion	Road and bridge restrictions	Lack of government incentives, directives and promotion

7.8 Conclusion

This chapter elaborates the opinions of strategic factor important weights across the stakeholder groups. It was found that the opinion among respondents was varied. With regard to the sustainable criteria, technical quality criteria appeared in all SWOT categories and considered as the most important sustainable criteria in global industry perspective. The interesting fact from the result was that different manufacturer groups had different opinions across the other stakeholder groups. The manufacturer groups perceived economic value as the most important criteria under strength category, while implementation and enforcement were the most important criteria under opportunity and threat category.

With regard to the strategic factors, the three most important factors under strength category were 'more highly durable buildings', 'greater job security', and 'compensation for earthquake reduction' factors. These three factors were in accordance with the three most important factors across the stakeholder groups, although they had different orders. This applied to weakness, opportunity and category as well. Under weakness category, the three most important factors were 'greater difficulties in making changes during construction', 'more complex connection designs', and 'higher initial investments'. Under opportunity category, the three most important factors were 'availability of equipment', 'higher needs for industrialization', and 'IAPPI facilitation of developing precast concrete systems'. Under threat category, the three most important factors were 'differences in quality and quantity of materials', 'lack of integrated standardization' and 'road and bridge restrictions'.

CHAPTER 8
STRATEGY FORMULATION

8.1 Introduction

Strategic planning can be somewhat simple, that is to analyse the current and expected future situation (Weihrich, 1982). SWOT analysis is usually conducted as the first step in strategic planning. However, SWOT analysis of precast concrete implementation in Indonesia is originally complicated because the stakeholders must view the SWOT factors from different standpoints. Quantification of SWOT by using IFAS and EFAS table (Wheelen and Hunger, 2012) is helpful in identifying the foremost internal and external factors which may be called critical success factors. This critical success factors are the factors on which future success and strategies should be based. The IFAS and EFAS table show the summary of the stakeholder group response (rating) and stakeholder group importance perception (weights) to the SWOT factors.

8.2 Identification of Precast Concrete Current Implementation Status

Understanding the current internal and external situation of precast concrete implementation, could help the industry to identify the current status and formulate alternative strategy. Internal Factor Analysis Summary (IFAS) organizes internal factors into strengths and weaknesses and how the stakeholder are responding to these specific factors. The rating column shows the stakeholder judgment regarding how well the precast concrete technology dealing with each specific internal factor in the form of mean value that has been elaborated in Chapter 6. The weight column shows the SWOT factor importance level to the present and future success of the precast concrete adoption in the form of eigenvector value that has been elaborated in Chapter 7. The total weighted score indicates how well the precast concrete technology is responding to current and expected factors in its internal environment. The result of IFAS is shown in Table 8-1.

Table 8-1. Internal Factor Analysis Summary (IFAS) table

		SWOT Factors	Weight	Rating	Weighted Score
STRENGTH	S.TQ.1	More highly durable buildings	0.199	4.139	0.825
	S.SC.1	Greater job security	0.165	3.972	0.655
	S.TQ.2	Compensation for earthquake reduction factor	0.151	3.472	0.525
	S.EP.1	More efficient material usage	0.111	4.333	0.481
	S.EP.2	Cleaner construction sites	0.111	4.306	0.479
	S.EV.4	Less scaffolding and formwork	0.050	4.583	0.229
	S.EV.2	More simplicity	0.053	4.250	0.226
	S.EV.3	Work in parallel	0.047	4.333	0.205
	S.EV.6	Less labor required	0.045	4.194	0.191
	S.EV.5	More success in meeting quality specifications	0.042	4.222	0.176
	S.EV.1	Smaller on-site area and staging space required	0.025	3.889	0.096
		Total			**4.088**
WEAKNESS	W.TQ.3	Greater difficulties in making changes during construction	0.229	4.000	0.915
	W.TQ.1	More complex connection designs	0.165	3.778	0.622
	W.EV.4	Higher initial investments	0.144	4.278	0.616
	W.EV.5	Heavy equipment dependent	0.125	4.556	0.570
	W.TQ.2	Greater loading difficulties for big components or long spans	0.141	3.583	0.504
	W.EV.2	Higher transportation costs	0.072	3.861	0.278
	W.EV.3	Licensing fees	0.073	3.333	0.245
	W.EV.1	Repetitious designs	0.051	3.722	0.191
		Total			**3.941**

External Factor Analysis Summary (EFAS) organizes external factors into opportunities and threats and how the stakeholder is responding to these specific factors. The rating column shows the stakeholder judgment regarding how well the precast concrete technology dealing with each specific external factor in the form of mean value that has been elaborated in Chapter 6. The weight column shows the SWOT factor importance level to the present and future success of the precast concrete adoption in the form of eigenvector value that has been elaborated in Chapter 7. The total weighted score indicates how the precast concrete technology is responding to current and expected factors in its external environment. The result of EFAS is shown in Table 8-2.

In this research, identification of precast concrete implementation was followed Marimin (2004) by calculating the IFAS and EFAS Score. Proper strategy formulation can be developed by locating the IFAS and EFAS score into SWOT Diagram. By using Equation 8 and 9 (Page 50), IFAS and EFAS score was 0.147 and

0.376, respectively and be considered the position of precast concrete implementation for low-cost housing in Indonesia is located in Strength-Opportunity Quadrant (Figure 8-1).

Table 8-2.External Factor Analysis Summary (EFAS) table

		SWOT Factors	Weight	Rating	Weighted Score
OPPORTUNITY	O.TQ.1	Availability of equipment	0.512	4.056	2.076
	O.IE.4	Higher needs for industrialization	0.113	4.028	0.457
	O.IE.5	IAPPI facilitation of developing precast concrete systems	0.110	3.917	0.431
	O.IE.3	Indonesian National Standard support	0.106	4.028	0.428
	O.IE.2	Ministerial regulation support	0.089	3.944	0.352
	O.IE.1	Available routine training by IAPPI	0.069	3.750	0.260
		Total			**4.003**
THREAT	T.TQ.1	Differences in quality and quantity of materials	0.434	3.611	1.568
	T.IE.1	Lack of integrated standardization	0.132	3.611	0.478
	T.IE.3	Road and bridge restrictions	0.100	3.611	0.361
	T.IE.2	Lack of government incentives, directives and promotion	0.094	3.306	0.312
	T.SC.4	Shortage of expertise and skilled labor	0.075	3.889	0.292
	T.SC.2	Limited public awareness	0.060	3.917	0.234
	T.SC.3	Development centralized in Java Island	0.058	3.556	0.206
	T.SC.1	Foreman-handyman culture difficult to change	0.046	3.806	0.175
		Total			**3.627**

Tirosh (2010) defined the four generic strategic directions from the simultaneous integration of the two external factors (opportunities and threats) with the two internal factors (strengths and weaknesses) (Page 35). Since the precast concrete status was located in Strength-Opportunity Quadrant, then the suitable strategy was Growth Strategy. The Growth strategy could be applied by market development, product development, vertical/horizontal integration, diversification, market penetration, mergers and acquisitions as in a synergic process to grow and expand.

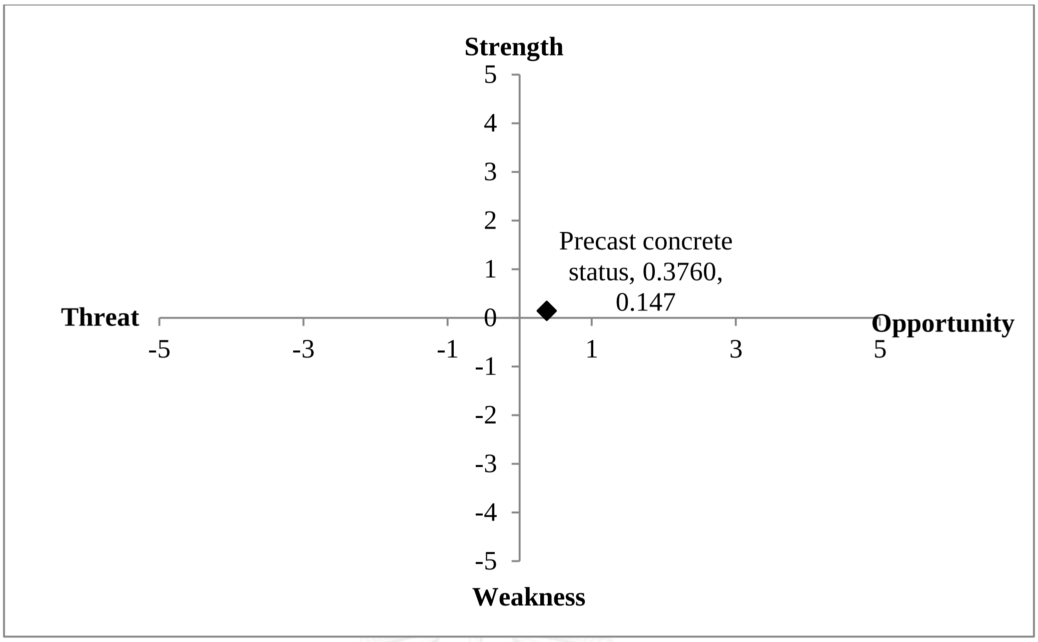


Figure 8-1.Current status of precast concrete implementation

8.3 Critical Factors of Precast Concrete Implementation in Indonesia

The critical factors of precast concrete implementation in Indonesia were determined by using grid of Importance – Response of IFAS and EFAS table. The horizontal cross-hair was 4 because the response toward all SWOT factors was more than average (value of 3). This cross-hair divided the area into major-minor strength, major-minor weakness, major-minor opportunity and major-minor threat. On the other hand, the vertical cross-hair was by the median value of each SWOT category. Median value was applied because the natural result of weight was ratio (Adamson and Prion, 2013). Median value divides frequency distribution exactly into two halves, thus, it can easily determine the more important area and the less important area. Moreover, there are few extreme values in the result, which were suitable to apply median when the data is skewed (Manikandan, 2011).

The industry perception map of strength factors are illustrated in Figure 8-2. The critical factors are the factors located on the more important area. In strength category, the median value for importance weight was 0.053. The strength factors that had importance weight more than 0.053 were "more highly durable buildings", "more efficient material usage", "cleaner construction sites", "greater job security", and "compensation for earthquake reduction factor". However, they had different intensities as strength. The first three factors mentioned were considered as major strengths. Hence, the factors must retain its good performance as competitive advantages of precast concrete. The rest of the factors considered as minor strengths, so improvement was needed to gain more competitive advantages.

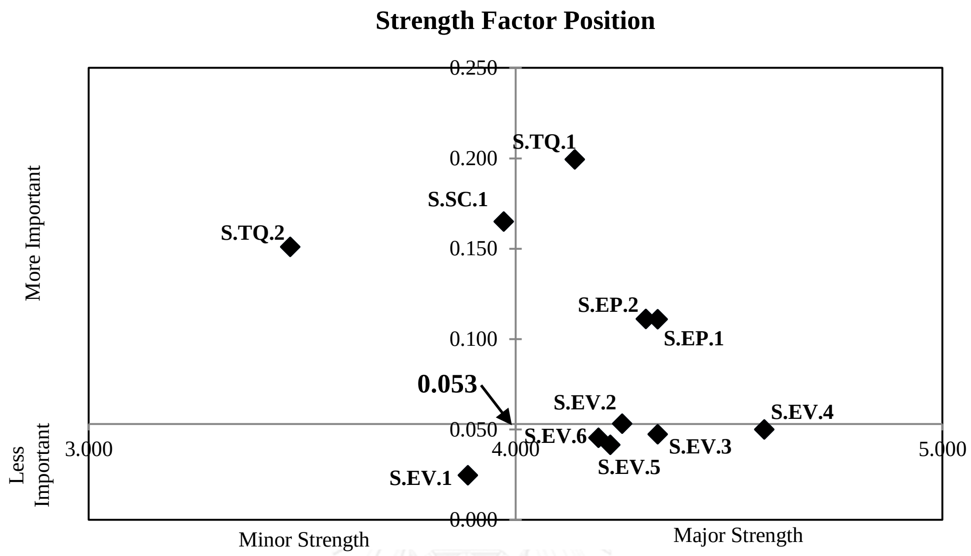


Figure 8-2.Industry perception map of strength factors

The industry perception map of weakness factors are illustrated in Figure 8-3. In weakness category, the median value for importance weight was 0.133. The weakness factors that had importance weights more than 0.133 were “greater difficulties in making changes during construction”, “higher initial investments”, “more complex connection design” and “greater loading difficulties for big components or long span”. The first two factors mentioned were considered as major weaknesses, hence, focus strategic steps must be taken to overcome this problem. The last two factors were considered as minor weaknesses, hence improvement for these factors are needed to eliminate the problems and increase the competitive advantages of precast concrete.

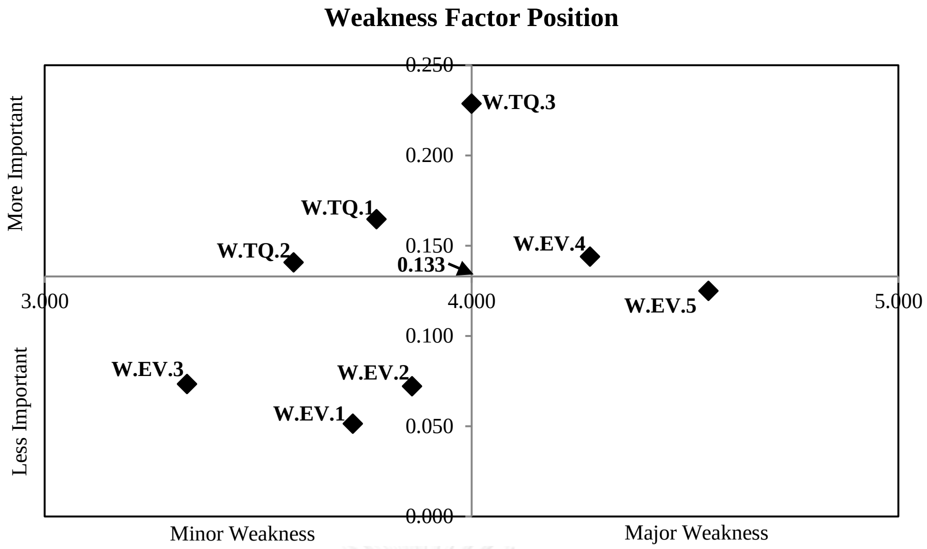


Figure 8-3.Industry perception map of weakness factors

The industry perception map of opportunity factors are illustrated in Figure 8-4. In opportunity category, the median value for importance weight was 0.108. The opportunity factors that had importance weights more than 0.108 were "availability of equipment", "higher needs of industrialization", and "IAPPI facilitation of developing precast concrete system". The first two factors mentioned were considered as major opportunity, hence, the factors must retain its good performance to support the success of precast concrete implementation. The last factor was considered as minor opportunity, so improvement was appropriate to more success implementation of precast concrete.

The industry perception map of threat factors are illustrated in Figure 8-5. In threat category, the median value for importance weight is 0.0845. The threat factors that had importance weight more than 0.0845 were "differences in quality and quantity of materials", "lack of integrated standardization", "road and bridge restriction", and "lack of government incentives, directives and promotions". All the factors get response value less than 4, meaning they were minor threats.

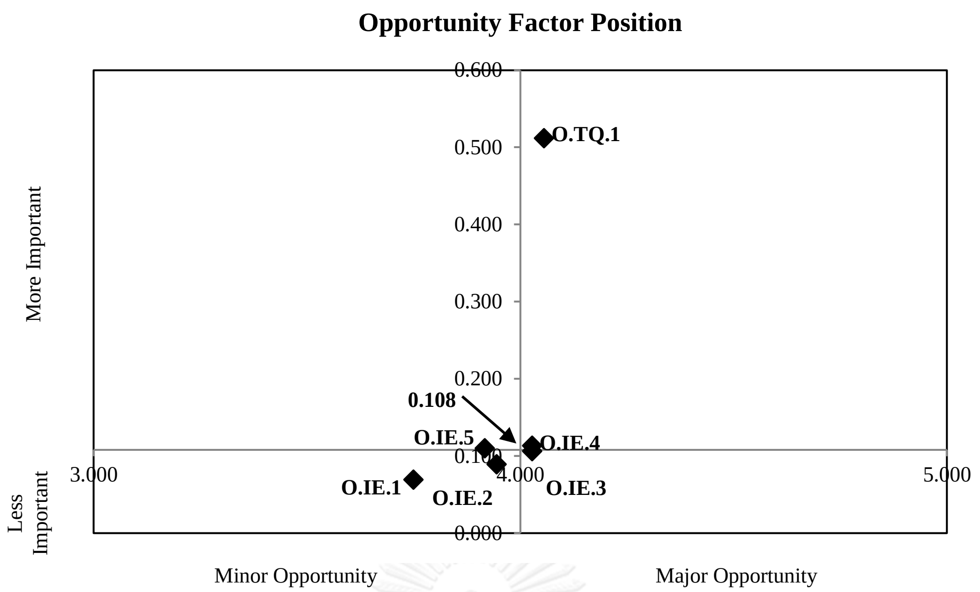


Figure 8-4.Industry perception map of opportunity factors

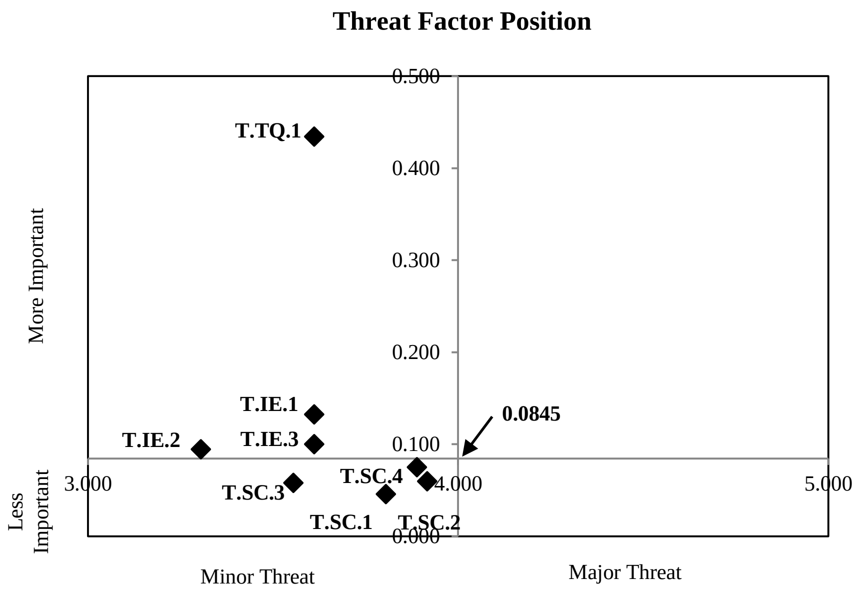


Figure 8-5.Industry perception map of threat factors

Finally, the critical factors from all SWOT categories have been determined. There were sixteen critical factors that come from strength (5 factors), weakness (4 factors), opportunity (3 factors), and threat (4 factors). The summary of sustainable implementation critical factors of precast concrete is illustrated in Table 8-3.

Table 8-3.Sustainable implementation critical factor of precast concrete in Indonesia

Sustainable SWOT Analysis	Strength	Weakness	Opportunity	Threat
Economic Value		• Higher initial investments		
Ecological Performance	• More efficient material usage • Cleaner construction sites			
Social Equity and Cultiure	• Greater job security			
Technical Quality	• More highly durable buildings • Compensation for earthquake reduction factor	• More complex connection designs • Greater loading difficulties for big components or long spans • Greater difficulties in making changes during construction	• Availability of equipment	• Differences in quality and quantity of materials
Implementation and Enforcement			• Higher needs for industrialization • IAPPI facilitation of developing precast concrete systems	• Lack of integrated standardization • Lack of government incentives, directives and promotion • Road and bridge restrictions

8.4 Discussion and Recommendation

According to the framework in strategy development by Optimat (2002) cited in Holton (2009), as shown in Figure 2-4, issue in this research has been identified as sustainable implementation of precast concrete for low-cost housing in Indonesia. This issue was elaborated by assessing strategic factors derived from sustainability pillars namely: economic value, ecological performance, social equity and culture, technical quality and implementation and enforcement. The strategic factors were analysed by SWOT analysis. There are thirty-three strategic factors have been identified and discussed in Chapter 4.

The next step was to prioritize the issues by quantifying the strategic factors in light of stakeholder response toward the factor and how they perceived importance of these factors to the industry. The result showed, in responding the strategic factors, there was no significant difference among various stakeholder organizations for the thirty-three strategic factors. The stakeholders also perceived the same three-most important factors under each SWOT category although prioritization among stakeholders was varied. Finally, the mean score of rating and importance weight value were multiplied to obtain weighted score for each factor. The weighted score of each SWOT category was then calculated into IFAS and EFAS scores to get the current position of precast concrete. Based on the calculation of IFAS and EFAS scores, the position of precast concrete implementation in Indonesia was in Strength-Opportunity quadrant, which Growth strategy was the suitable generic strategy to apply.

Application of strategy cannot be not only coming from the identified generic strategy, but also understanding the critical factors to be more focus on the problem. There were 16 strategic factors considered as critical, that can be used to develop more detailed strategy for each stakeholder. Some discussions and recommendations of critical factors were provided below.

The ability of precast concrete to compensate earthquake reduction factor may result in the weakness of more complex connection design to achieve appropriate seismic design, because most of region in Indonesia is located in active seismic areas. Precast concrete might be more expensive, especially because it involves high initial capital investment and dependent on heavy equipment such as cranage that results in higher cost for equipment compare with the conventional construction. However, although the critical investment in the initial process is very high, the opportunity of higher needs for industrialization is there, hence, once break-even point is reached, the benefits from the precast concrete will increase with the number of units produced (Chen *et al.*, 2010a). Moreover, as in the emergence of good performance in critical strength factors of “cleaner construction site” and “more efficient material usage” improve the construction performance in environmental sustainability. By implementing precast concrete, Indonesia is on the right track for moving forward to develop the country in sustainable way. Other developing countries, such as Thailand, Malaysia and Singapore, are also moving in the same direction.

Based on the quantification of SWOT analysis, the current status of precast concrete implementation in Indonesia is in the Growth direction. However, extension alternative strategies can be derived from the combination of specific SWOT critical factors. It can be seen from Table 8-4, there are four alternative strategies in SWOT matrix (Weihrich, 1982). The strategy identified as SO to use strengths to take advantage of opportunities. The WO strategy is to take advantage of opportunities by overcoming weaknesses. The ST strategy is to use strengths to avoid threats. The last is WT strategy is to minimize weaknesses and avoid threats.

The author offers recommendation of alternative strategies based on the critical factors and available generic strategies ((Warszawski, 1996); (David, 2011)), which are flexible to change depends on the market and stakeholder needs. Market development is adding market for development of present product or group of products (David, 2011). All the critical factors of precast concrete strength, are supported by the opportunity of “availability of equipment and “higher needs of industrialization”. Precast concrete market can be expanded to not only public residential building but also to other public building and private residential building projects.

Product development are modification and improvement of existing products in existing markets (David, 2011). This strategy is suitable because of the critical factor in opportunity of “IAPPI facilitation of developing precast concrete system”, as well as overcoming the critical factors in weakness.

Table 8-4.The SWOT matrix of precast concrete implementation

TOWS MATRIX **(Weihrich, 1982)**	**Strengths (S)** - More highly durable building - More efficient material usage - Cleaner construction sites - Greater job security - Compensation for earthquake reduction factor	**Weaknesses (W)** - Greater difficulties in making changes during construction - More complex connection in design - Higher initial investments - Greater loading difficulties for big components and longer spans
Opportunities (O) - Availability of equipment - Higher needs of industrialization - IAPPI facilitation of developing precast concrete system	**SO Strategies** **(**Generate strategies that use **strengths** to take **advantage** of **opportunities)** 1. Market development 2. Market Penetration 3. Product development	**WO Strategies** **(**Generate strategies that take **advantage** of **opportunities** by **overcoming weaknesses)** 1. Product development 2. Focus 3. Market penetration
Threats (T) - Differences in quality and quantity of materials - Lack of integrated standardization - Road and bridge restriction - Lack of government incentives directives and promotion	**ST Strategies** (Generate strategies that use **strengths** to **avoid threats)** 1. Careful selection of suppliers 2. Technological advance 3. Training of personnel 4. Incentive programs 5. Investments in infrastructure	**WT Strategies** (Generate strategies that **minimize weaknesses** and **avoid threats)** 1. Standardization of products 2. Training of personnel

Market penetration is seeking increased market shares for present products of services in present markets through greater marketing efforts (David, 2011). The emergence of “higher needs of industrialization”, in the present market of public residential housing, it is possible to increase good publicity effort to overcome the bad publicity because of leakage between the joint of panels. Other strategies include in market penetration are increasing the number of salespersons, increasing advertising expenditures and offering extensive sales promotion items (David, 2011).

Focus is applying cost leadership or differentiation to a very narrow segment of the market. Cost leadership means to be less expensive than competitors, whereas, differentiation means provide more attractive product by making it different and more valuable than the competitor’s product (Warszawski, 1996). Focus strategy can be applied to geographical areas, where it has less seismic activity such as Kalimantan to reduce the complexity of connection design. Focus strategy in geographical areas also includes intimate relationships with clients, suppliers, and authorities in a particular region, and offers a better service (Warszawski, 1996).

Careful selection of suppliers is important because a major share of the cost of construction projects are come from materials and services supplied from outside (Warszawski, 1996). The right supplier is expected to have good quality of materials with on time delivery by reasonably cheap price, and the right level of service. This is suitable to avoid the threat of “differences in quality and quantity of materials”, as well as use the strength of “more efficient material usage”. Continuous monitoring of the suppliers and utilization of any type of advantage such as in quality purchase or payment terms proposed to a supplier to obtain a price discount that lead to a significant cost reduction (Warszawski, 1996).

Utilization of advanced technologies can save both in labor and materials that are lead into considerable cost savings and price reduction under proper market circumstances (Warszawski, 1996). All the critical factors of strength will have optimum performance when technological advance applied, such as automation in precast concrete production, and high-strength concrete.

Training of personnel in working procedures with the orientation towards maximum saving of time and elimination of waste will conceivably result in reduced cost (Warszawski, 1996). By the professionalism of the workers, all the critical factors in strength can achieve its optimum performance. The adequate management knowledge of worker will also be useful when they experience the critical factors of threat.

Programs from the Government such as incentives, directives, and promotions help to improve the national usage of precast concrete. Government have the ability to create the necessary institutional enablers to improve the business case and build the capacity and skills levels of the industry through its own procurement practices, incentive programmes and taxation (Du Plessis, 2007). For example, Malaysian Government provides many programs to the success implementation of Industrialised Building System (IBS). Incentive is given in the form of exemption of the construction levy (0.125% of total cost of the project) for contractors that used IBS at least 50% and tax incentive also offered through Accelerated Capital Allowance (ACA) for the purchase of moulds used for production precast concrete components (Shaari, 2006). The movement to mechanization of the Malaysian construction industry to achieve labour reduction, better cost, quality, safety, and speed, and increase productivity. Strategies were proposed to achieve this goal that consists of tax incentives for equipment and machinery, marketing, awareness and equipment rental (Bahri, 2012).

The Singapore Construction Industry Development Board has produced many publications regarding construction by precast concrete in Buildability Series. Housing Development Boards (HDB) of Singapore team of Civil and Structural engineers have developed the Automated Precast Production system (APPS), which has increased HDB's production capacity of precast elements by 40-45%. Test-bedding of APPS has also enabled HDB to develop a wider variety of designs for precast elements for extensive use in constructing HDB flats (HDB Singapore, 2014)

Investments in infrastructure can make land, labor, and physical capital more productive that facilitates the transport of goods or the provision of power (Wang, 2002). Proper and adequate infrastructure can lead to lower cost of transportation that results in competitive price of precast concrete.

Standardization of products can improve the efficiency of design and construction, save costs, and reduce prices (Warszawski, 1996). Modular coordination principle is one of efforts in standardization of product because every manufacturer can follow the guideline. Standardization of sizes of commonly used precast concrete will encourage application and help to make the production more economical (Building and Construction Authority (1997) of Singapore)

The action of any aforementioned strategies depends on the type of stakeholder. Each of stakeholders (government, manufacturer, contractor, consultant/designer, and professional association) has their own roles, which the implementation of strategies cannot be on one's own. Sustainable implementation of precast concrete cannot be formulated by a small group of experts gathered in a conference room. It can only come from a dialogue between the different levels of stakeholders that formulate the global strategy in a local context and responds to local needs and priorities (Du Plessis, 2007).

The research is not include testing the strategy, and reviewing and adapting strategy as in the framework of strategy development of Optimat (2002) because of time and cost limitation. Moreover, each stakeholder has their own role in applying specific strategy. The identified critical factors can be used as the guideline of stakeholder in understanding the industry situation to develop the action plan and strategy.

8.5 Conclusion

This chapter presents the results of IFAS and EFAS analysis. According to the calculation of IFAS and EFAS total weighted scores, the position of precast concrete implementation for low-cost housing in Indonesia was located in Strength-Opportunity Quadrant which can implement the Growth Strategy.

The critical factors from all SWOT categories have been determined by locating the strategic factors on the grid of IFAS and EFAS importance-performance. There are sixteen critical factors involving the five sustainability pillars that come from strength (5 factors), weakness (4 factors), opportunity (3 factors), and threat (4 factors).

CHAPTER 9
RESEARCH CONCLUSIONS

9.1 Research Findings

The aim of this research was to conduct situational analysis of industrialized precast concrete by assessing its sustainability criteria to build low-cost housing in Indonesia. This research has fulfilled the aim of the research, by answering the projected research objectives:

1. To explore–perceptions of various stakeholder of strategic factors in precast concrete implementation

There were thirty-three strategic factors that have been identified. The result showed, in responding the strategic factors, there was no significant difference among various stakeholder organizations for the thirty-three strategic factors. The stakeholders also perceived the same three-most important factors under each SWOT category although prioritization among stakeholders was varied. The results indicated that the global industry perceive technical quality as the most important criteria under all SWOT categories. The interesting fact from the result was that the manufacturer group had different opinions across the other stakeholder groups. The manufacturer group perceives economic value as the most important criteria under strength category.

2. To evaluate the current implementation status of precast concrete in low-cost housing based on identified strategic factors

According to the calculation of IFAS and EFAS total weighted score, the position of precast concrete implementation for low-cost housing in Indonesia was located in Strength-Opportunity Quadrant which can implement the Growth Strategy.

3. To identify critical factors significant in improving sustainability efforts for precast concrete implementation

Under the strength category, the factors were “more highly durable buildings”, “greater job security”, “compensation for earthquake reduction factor”, “cleaner construction site” and “more efficient material usage”. Under the weakness category, the factors were “greater difficulties in making changes during construction”, “higher initial investments”, “more complex connection design” and “greater loading difficulties for big components or long span”. Under opportunity category, the factors were “availability of equipment”, “higher needs of industrialization”, and “IAPPI facilitation of developing precast concrete system”. Under the threat category, the factors were “differences in quality and quantity of materials”, “lack of integrated standardization”, “road and bridge restriction”, and “lack of government incentives, directives and promotions”.

9.2 Research Contributions

This research gives contributions to precast industry in Indonesia as follows:

1. As a guideline to the government stakeholders to build strategy and policy to improve the business.
2. As a guideline to manufacturers and contractors to enter the business and build strategy.

9.3 Research Limitations

This research has developed the situational analysis in strategic framework for sustainable implementation for precast concrete for low-cost housing in Indonesia and has provided systematic approach for stakeholders to improve the performance of precast concrete based on critical factors. However, some delineation drawn in this research in order to keep the study focused specifically on the research objectives. This meant the research was limited in the aspects:

- Due to the data sampling process, this research focused more on the application of precast load bearing wall system for low-cost housing by Indonesian Government particularly under the supervision of Ministry of Public Works and Human Settlement. For the private sector, the response and prioritization on the strategic factors may have minor differences due to the stakeholder priority and nature of works.

- Stakeholder group selection was not include the end-user, because the object of the research was public housing by government, where the end-user has indirect participation in the construction of this type of project.
- Due to the time and cost limitation, this scope of research were (1) to identify issues, (2) to prioritise issues and (3) to develop (generic) strategy based on Optimat (2002) framework of strategy development as the guideline of each stakeholder in understanding the industry situation to develop particular stakeholder action plan and strategy.
- Most of stakeholder domiciled in Java Island, although they also have experiences conducting projects outside of Java, the results may thus represent Java Island. However, Indonesia has a vast territory that each region has different nature characteristics. For example, if the population of research only focused in the non-earthquake region like Kalimantan, the factor "compensation for earthquake reduction factor" could get the least attention from the respondents compare with the current result.
- The measurement of each strategic factor was merely based on opinion of stakeholder that used experience and feeling as judgment in giving rating for response and importance weight. Therefore, the result of this research was based on the expertise perception of the stakeholder group.

9.4 Further Study

This research provides more opportunities for exploring each strategic SWOT factor in more comprehensive way to cope with the mentioned limitation of research.

- Research on precast concrete implementation on private projects where the owner is the end-user, not the government. It could provide interesting result to increase the business of precast concrete not only for public projects, but also private projects, hence the market situation for precast concrete implementation can be seen as a whole country.

- Research in the implementation and evaluation of strategy to get robust strategic plan of precast concrete implementation in Indonesia.

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APPENDICES

APPENDIX A

Document Set for Data Collection I (Interview)

CHULALONGKORN UNIVERSITY
Department of Civil Engineering, Faculty of Engineering

COVERING LETTER

To Whom it May Concern,

<u>Research Survey – Master Programme</u>

I am currently undertaking a Master programme in Construction Engineering and Management, Civil Engineering Department, Faculty of Engineering at Chulalongkorn University, Bangkok, Thailand. In fulfilment of this Master programme, I am required to conduct a survey to get a clear picture from industry. The topic is ‘Strategic Framework for Sustainable Implementation of Precast Concrete for Low-Cost Housing in Indonesia’ and I am investigating the following aspects:

1. Explore different perceptions of various stakeholder in precast concrete implementation
2. Evaluate the current implementation status of precast concrete in low-cost housing.
3. Identify critical factors significant in improving sustainability efforts for precast concrete implementation

In regard for data collection, I would like to ask permission to get contact lists of stakeholder concerned for low-cost housing (Rusunawa) from IAPPI, such as: Government including Ministry of Public Works and Human Settlement, Contractor, Manufacturer and Designer. Along with this letter, I attached the interview guidelines to be considered.

Thank you very much for your assistance.

Yours faithfully,
Researcher,

<u>Joan Kartini Rossi</u>

Survey on Master Research

Strategic Framework for Sustainable Implementation of Precast Concrete for Low-Cost Housing in Indonesia

Background:
Indonesian government encourages the use of precast concrete due to its advantages to construct low-cost housing, i.e. its good quality and fast construction. Despite all the advantages and economic opportunities, precast concrete is not popular in Indonesia. The barriers such as huge capital investments became the reason that the use of precast concrete is inferior to other building materials.

Objective:
This interview aims to identify the **strengths, weaknesses, opportunities and threats list** regarding to sustainable criteria for precast concrete implementation for low-cost housing in Indonesia. Once the factors are identified, they will be analysed to develop perception map of stakeholders for the use of precast concrete for low-cost housing in Indonesia.

Private and Confidential:
All response will be kept strictly confidential and will be only used for research purposes.

Survey Time Frame:
It is anticipated that interview will take approximately 30-40 minutes to complete.

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CHULALONGKORN UNIVERSITY
Bangkok, Thailand

CONSENT FORM FOR CHULALONGKORN UNIVERSITY RESEARCH PROJECT

Strategic Framework for Sustainable Implementation of Precast Concrete for Low-Cost Housing in Indonesia

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STATEMENT OF CONSENT

By signing below, you are indicating that you:

(Please tick (√) all that apply)

- ☐ have read and understood the information document regarding this project
- ☐ have had any questions answered to your satisfaction
- ☐ understand that if you have any additional questions you can contact the research team
- ☐ understand that you are free to withdraw at any time, without comment or penalty
- ☐ understand that the project will include audio recording
- ☐ agree to participate in the project with recording

or

- ☐ agree to participate in the project without recording

Name____

Signature______________________________________

Date __________ / ____________ / ____________

Please return this sheet to the investigator

Interview Guidelines

A. Respondent's Demography

(Please check all that apply)

Organisation:

- ☐ Government
- ☐ Contractor
- ☐ Manufacturer
- ☐ Designer
- ☐ Other:……………..

Years of experience in construction industry:

☐ <5 years	☐ 11 – 25 years	☐ >35 years
☐ 5 – 10 years	☐ 26 – 35 years	

Projects participations using precast concrete:

☐ <5 years	☐ 11 – 25 years	☐ >35 years
☐ 5 – 10 years	☐ 26 – 35 years	

Precast concrete implementation:

- ☐ Half precast concrete system
- ☐ Fully precast concrete system

B. Interview questions

1. Please lists the strengths, weaknesses, strengths, weaknesses, opportunities and threats regarding sustainability criteria namely: economic value, ecological performance, social equity and culture, technical quality, and implementation and enforcement for precast concrete implementation for low-cost housing in Indonesia.

Strengths:	**Weaknesses:**
Economic value: *Ecological performance:* *Social Equity and Culture:* *Technical Quality:* *Implementation and Enforcement:*	*Economic value:* *Ecological performance:* *Social Equity and Culture:* *Technical Quality:* *Implementation and Enforcement:*
Opportunities:	**Threats:**
Economic value: *Ecological performance:* *Social Equity and Culture:* *Technical Quality:* *Implementation and Enforcement:*	*Economic value:* *Ecological performance:* *Social Equity and Culture:* *Technical Quality:* *Implementation and Enforcement:*

APPENDIX B

Document Set for Data Collection II
(Questionnaire)

Survey on Master Research

Strategic Framework for Sustainable Implementation of Precast Concrete for Low-Cost Housing in Indonesia

Background:
Precast bearing wall is gaining popularity for housing in developed countries due to its advantages in quality, faster completion time project and economically effective. Among ASEAN Countries, Singapore and Thailand (Figure below) have extensive use of this technology, particularly for housing (landed-house and condominium) construction. Indonesia starts to use precast bearing wall for low-cost housing (*Rusunawa*) by waffle-crete technology at Cengkareng, Tangerang. However, the use of precast bearing wall in Indonesia is not sustained. Therefore, research is needed to evaluate why it is not gain much attention.

Objective:
This questionnaire aims to get your perception regarding SWOT factors for precast bearing wall adoption for *Rusunawa* in Indonesia. The SWOT factors considering five pillars of sustainability namely: economical value, ecological performance, social equity and culture, technical quality, and implementation and enforcement. Once the factors are identified, it will be analysed to develop stakeholders' perception map of the adoption of precast bearing wall for *Rusunawa* in Indonesia.

Questionnaire structure:
The questionnaire consists of three parts:
1. Respondent demographics
2. Evaluation of SWOT factors
3. Pairwise comparison of SWOT factors

Confidentiality:
All responses will be kept strictly confidential and will be only used for research purposes.

Survey Time Frame:
It is anticipated that interview will take approximately 20 – 30 minutes to complete.

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Questionnaire Structure

1. Respondent's Demographics

(Please check all that apply)

Name :
Company Name :
Email :

Organisation:

- ☐ Government
- ☐ Contractor
- ☐ Manufacturer
- ☐ Designer
- ☐ Other:……………..

Position:

- ☐ Director
- ☐ Engineer
- ☐ Architect
- ☐ Project Manager
- ☐ Quantity Surveyor
- ☐ User
- ☐ Academician/Researcher
- ☐ Other:……………..

Years of experience in construction industry:

- ☐ <5 years
- ☐ 5 – 10 years
- ☐ 11 – 25 years
- ☐ 26 – 35 years
- ☐ >35 years

Projects participations using precast concrete:

- ☐ <5 years
- ☐ 5 – 10 years
- ☐ 11 – 25 years
- ☐ 26 – 35 years
- ☐ >35 years

2. Evaluation of SWOT factors

This section consists of four parts namely Strength, Weakness, Opportunity, Threat factors of precast bearing wall adoption. With your knowledge and experience, please assign a rating to each factor from 1 (strongly disagree) to 5 (strongly agree) with the statement by clicking the appropriate scale.

Instructions:
Mark the scale which is most suitable **in your own opinion**.

Scale 1 represents “strongly disagree”
Scale 2 represents “disagree”
Scale 3 represents “average”
Scale 4 represents “agree”
Scale 5 represents “strongly agree”

For example if you feel strongly agree to the factor “smaller on-site area and staging space required” then you can mark scale 5.

smaller on-site area and staging space required	1	2	3	4	X

Strengths* Factor of Precast Bearing Wall Adoption	**Strongly Disagree**	↔			**Strongly Agree**
• **Smaller on-site area and staging space required** Minimum area to be used because production done in factory and can apply just-in-time delivery method that can reduce area of stockyard. *Area proyek yang digunakan minimal karena produksi dilakukan di pabrik dan dapat mengaplikasikan metode pengiriman tepat waktu sehingga mengurangi kebutuhan area penyimpanan.*	1	2	3	4	5
• **More simplicity** Number of items to control at project site are less because the production phase done in factory. *Jumlah item yang dikontrol di proyek lebih sedikit karena produksi telah dilakukan di pabrik.*	1	2	3	4	5
• **Work in parallel** Parallel schedule of production and erection allows for simultaneous works time, thus faster completion of time. *Jadwal produksi dan ereksi yang dapat dilakukan secara bersamaan memungkinkan waktu kerja yang simultan sehingga dapat mempersingkat waktu pelaksanaan konstruksi.*	1	2	3	4	5
• **Less scaffolding and formwork** The less use of wood for scaffolding and formwork enhance environmental friendly and reduce the cost of it. *Mengurangi penggunaan kayu untuk perancah dan bekisting mengurangi kebutuhan biaya tersebut dan lebih ramah lingkungan.*	1	2	3	4	5
• **More success in meeting quality specifications**	1	2	3	4	5

Quality control on the ground minimize failures of structural and architectural ability and reduce the cost of re-work and/or finishing. *Pengendalian kualitas di tanah mengurangi kegagalan spesifikasi struktur dan arsitektur serta mengurangi biaya untuk perbaikan dan/atau pekerjaan finishing.*					
• **Less labor required** Numbers of labor on site are less: easy to control absence and cost effective. *Jumlah pekerja di lapangan sehingga lebih mudah untuk pengendalian kehadiran dan efektifitas biaya.*	1	2	3	4	5
• **More efficient material usage** Efficiently managed construction material and reduces the amount of unwanted materials left over during construction and production, therefore cost effective. *Manajemen material konstruksi secara efisien dan mengurangi jumlah sampah material pada saat produksi dan konstruksi, sehingga penggunaan biaya efektif.*	1	2	3	4	5
• **Cleaner construction sites** Production done in factory can reduce the amount of unwanted materials left over in construction site and makes better dust control. *Produksi dilakukan di pabrik dapat mengurangi jumlah material buangan yang tersisa di pabrik dan pengendalian debu lebih baik.*	1	2	3	4	5
• **Greater job security** Labor professionalism demands make job security for labor is increase. *Permintaan profesionalisme pekerja meningkatkan tersedianya lapangan pekerjaan yang berkesinambungan.*	1	2	3	4	5
• **More highly durable buildings** Have long usable life and better technical quality. *Memiliki umur penggunaan yang panjang dan kualitas teknik lebih baik.*	1	2	3	4	5
• **Compensation for earthquake reduction factor** Concrete panels have the inherent strength to perform as shear walls with little or no additional reinforcement. The inherent ease of defining load paths through connections is relatively easy to separate precast concrete lateral force resisting systems performance from that of the vertical load bearing frame. *Panel beton memiliki kekuatan untuk berlaku sebagai dinding geser dengan sedikit atau tanpa tulangan tambahan. Kemudahan untuk mendefinisikan jalur pembebanan melalui sambungan relatif mudah untuk memisahkan kinerja sistem tolakan gaya lateral beton pracetak dari kerangka pemikul vertikal.*	1	2	3	4	5

*Kelebihan penerapan sistem dinding pemikul pracetak

Weaknesses* Factor of Precast Bearing Wall Adoption	Strongly disagree ↔				Strongly agree
• **Repetitious designs** Repetition design is required in order to achieve cost efficiency (economies of scale). *Rancangan yang berulang merupakan persyaratan untuk mencapai efisiensi biaya (skala ekonomi).*	1	2	3	4	5
• **Higher transportation costs** Frequent transportation of panels from factory to site and special handling is needed when delivery. *Seringnya frekuensi transportasi panel dari pabrik ke lokasi proyek dan perhatian lebih dalam penanganan dibutuhkan pada saat pengiriman.*	1	2	3	4	5
• **Licensing fees** The precast inventors have to register their product which is costly. *Biaya pendaftaran yang mahal untuk mendaftarkan sistem pracetak agar dapat diaplikasikan.*	1	2	3	4	5
• **Higher initial investments** The factory set-up and material purchase have to done in initial phase of construction which makes the cost curve is high in the front. *Pendirian pabrik dan pembelian material harus dilakukan di fase awal konstruksi sehingga kurva pembiayaan mahal di awal.*	1	2	3	4	5
• **Heavy equipment required** Heavy equipment is needed to handle and erect the precast panels. *Alat berat dibutuhkan untuk penanganan dan ereksi panel pracetak.*	1	2	3	4	5
• **More complex connection designs** The connection is prone to leakage, therefore strict supervision and skilled labor is required to achieve the quality. *Rentan terjadinya kebocoran di sambungan, sehingga pengawasan yang ketat dan pekerja yang terampil dibutuhkan untuk mencapai kualitas yang diinginkan.*	1	2	3	4	5
• **Greater loading difficulties for big components or long spans** Big component or long span is difficult to handle. *Komponen yang besar atau bentang yang panjang sulit untuk ditangani.*	1	2	3	4	5
• **Greater difficulties in making changes during construction** Production is on going, which is costly if wants to have changes. *Perubahan yang dilakukan pada setelah tahap desain membutuhkan biaya yang mahal.*	1	2	3	4	5

*Kelemahan penerapan sistem dinding pemikul pracetak

Opportunities* Factor of Precast Bearing Wall Adoption	Strongly disagree ↔ Strongly agree				
• **Availability of equipment** The heavy equipment needed to support precast concrete work is available sufficiently. *Alat berat yang dibutuhkan untuk mendukung pekerjaan beton pracetak cukup tersedia.*	1	2	3	4	5
• **Available routine training by IAPPI** The routine training to disseminate the knowledge of precast concrete held by IAPPI and Public Work Ministry held periodically. *Pelatihan untuk menyebarluaskan pengetahuan beton pracetak oleh IAPPI dan Kementerian Pekerjaan Umum dilakukan secara rutin.*	1	2	3	4	5
• **Ministerial regulation support** Precast concrete is recommended material to use in vertical high-rise low-cost housing (Permen PU 05/PRT/M/2007). *Beton pracetak merupakan material yang direkomendasikan dalam pembangunan rumah susun sederhana bertingkat tinggi* (Permen PU 05/PRT/M/2007).	1	2	3	4	5
• **Indonesian National Standard support** Indonesian National Standard produces standard for unit pricing, designing and structural calculation for precast concrete. *Standar Nasional Indonesia telah mengeluarkan standar harga satuan, rancangan dan perhitungan struktur untuk beton pracetak.*	1	2	3	4	5
• **Higher needs for industrialization** The need to provide housing is very huge that industrialization can support its cost and resources effectively and efficiently. *Kebutuhan penyediaan rumah sangat besar sehingga industrialisasi dapat mendukung efektivitas dan efisiensi biaya dan sumberdaya.*	1	2	3	4	5
• **IAPPI facilitation of developing precast concrete systems** The precast concrete inventor will be mentoring by IAPPI. *Penemu sistem beton pracetak akan didampingi oleh IAPPI.*	1	2	3	4	5

*Peluang yang dapat membuat sistem dinding pemikul pracetak dapat berkembang

Threats* Factor of Precast Bearing Wall Adoption	Strongly disagree ↔ Strongly agree				
• **Foreman-handyman culture difficult to change** Foreman-handyman culture is deeply-rooted makes a big gaps in precast concrete adoption *Budaya mandor-tukang sudah sangat mengakar sehingga terdapat jarak yang sangat besar untuk mengadopsi sistem beton pracetak dan sulit melakukan perubahan.*	1	2	3	4	5
• **Limited public awareness** Precast concrete is not a new technology but the knowledge of public are limited and afraid to take risk in adopting it. *Beton pracetak bukan merupakan teknologi baru tetapi pengetahuan masyarakat masih terbatas dan takut mengambil resiko untuk mengadopsi teknologi tersebut.*	1	2	3	4	5
• **Development centralized in Java Island**	1	2	3	4	5

The development of technology and human resources limited in Java island. Where other region such as Kalimantan has potential in adopting precast concrete because it is not located in earthquake area and has rapid economic growth. *Pengembangan teknologi dan sumberdaya manusia terbatas di Pulau Jawa. Dimana di daerah lain seperti Kalimantan memiliki potensi untuk mengadopsi beton pracetak karena tidak terletak di wilayah yang rentan gempa dan memiliki pertumbuhan ekonomi yang sangat tinggi kurang mendapat perhatian.*					
• **Shortage of expertise and skilled labor** Insufficient expertise and skill labor to adopt precast concrete. *Kurangnya tenaga ahli dan tenaga terampil untuk mengadopsi beton pracetak.*	1	2	3	4	5
• **Differences in quality and quantity of materials** Availability and quality of material is different in each region. *Ketersediaan dan kualitas material berbeda di setiap daerah.*	1	2	3	4	5
• **Lack of integrated standardization** The standardization of designs that can fulfill requirements of road and bridge restriction, handling process, earthquake factor and so on are not integrated. *Standardisasi rancangan untuk memenuhi persyaratan kemampuan jalan dan jembatan, proses penanganan, faktor gempa dan lain lain tidak terintegrasi.*	1	2	3	4	5
• **Lack of government incentives, directives and promotions** IAPPI have limited support from government. *IAPPI atau precaster secara umum mendapatkan dukungan yang terbatas dari pemerintah.*	1	2	3	4	5
• **Road and bridge restrictions** Road and bridge designs are not support the delivery and poor road condition makes delivery difficult without changing the quality of precast panels. *Kemampuan jalan dan jembatan tidak mendukung proses pengiriman dan kondisi jalan yang buruk membuat proses pengiriman tanpa terjadinya perubahan kualitas pada panel pracetak sulit.*	1	2	3	4	5

*Tantangan dalam penerapan beton pracetak

3. Pairwise comparison of SWOT factors

The following pages will ask you to rank the relative importance of pairs under each SWOT factor. Your pair-wise prioritizations will be analysed to produce an overall ranking of these areas for analysis.

Instructions:

If you opine both factors have the same level of importance, give mark under equal column.

Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Smaller on-site area and staging space required				X				More simplicity

- If you feel the factor on the left is more important than the factor on the right, give mark on the three-most-left column (choose only one based on the intensity: very strong/strong/average).

Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Smaller on-site area and staging space required		X						More simplicity

- If you feel the factor on the right is more important than the factor on the left, give mark on the three-most-right column (choose only one based on the intensity: very strong/strong/average).

Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Smaller on-site area and staging space required							X	More simplicity

A. Pairwise comparison under Strength category

Under strength divided into four sustainability criteria namely **economical value, ecological performance, social equity and culture, and technical quality**. Please rank the relative importance of pairs under each sustainability category.

Which of the following factorsdo you think is more important?

	Strengths							
	← MORE — Comparison Levels — MORE →							
Factor	**Very strong**	**Stron g**	**Aver age**	**Equal**	**Averag e**	**Strog**	**Very strong**	**Factor**
Economic value								
Smaller on-site area and staging space required								More simplicity
Smaller on-site area and staging space required								Work in parallel
Smaller on-site area and staging space required								Less scaffolding and formwork
Smaller on-site area and staging space required								More success in meeting quality specifications
Smaller on-site area and staging space required								Less labor required
More simplicity								Work in parallel

More simplicity							Less scaffolding and formwork
More simplicity							More success in meeting quality specifications
More simplicity							Less labor required
Work in parallel							Less scaffolding and formwork
Work in parallel							More success in meeting quality specifications
Work in parallel							Less labor required
Less scaffolding and formwork							More success in meeting quality specifications
Less scaffolding and formwork							Less labor required
More success in meeting quality specifications							Less labor required
Ecological performance							
More efficient material usage							Cleaner construction sites
Social equity and culture							
Greater job security							
Technical quality							
More highly durable buildings							Compensation for earthquake reduction factor

According to the answer for strength factors, which sustainability criteria is more important?

	Sustainability criteria under Strength category							
	← **MORE— Comparison Levels — MORE** →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Economic value								Ecological performance
Economic value								Social equity and culture
Economic value								Technical quality
Ecological performance								Social equity and culture
Ecological performance								Technical quality
Social equity and culture								Technical quality

B. Pairwise comparison under Weakness category

Under weakness divided into two sustainability criteria namely **economical value and technical quality.** Please rank the relative importance of pairs under each sustainability category.

Which of the following factors do you think is more important?

	Weaknesses							
	← MORE — Comparison Levels — MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Economic value								
Repetitious designs								Higher transportation costs
Repetitious designs								Licensing fees
Repetitious designs								Higher initial investments
Repetitious designs								Heavy equipment dependent
Higher transportation costs								Licensing fees
Higher transportation costs								Higher initial investments
Higher transportation costs								Heavy equipment dependent
Licensing fees								Higher initial investments
Licensing fees								Heavy equipment dependent
Higher initial investments								Heavy equipment dependent
Technical quality								
More complex connection designs								Greater loading difficulties for big components or long spans
More complex connection designs								Greater difficulties in making changes during construction
Greater loading difficulties for big components or long spans								Greater difficulties in making changes during construction

According to the answer for threat factors, which sustainability criteria is more important?

	Sustainability criteria under Weakness category							
	← MORE — Comparison Levels — MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Avera ge**	**Strong**	**Very strong**	**Factor**
Economic value								Technical quality

C. Pairwise comparison under Opportunity category

Under opportunity divided into two sustainability criteria namely **technical quality and Implementation and enforcement**. Please rank the relative importance of pairs under each sustainability category.

Which of the following features do you think is more important?

	Opportunities							
	← MORE—— Comparison Levels—— MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Technical quality								
Availability of equipment								
Implementation and Enforcement								
Available routine training by IAPPI								Ministerial regulation support
Available routine training by IAPPI								Indonesian National Standard support
Available routine training by IAPPI								Higher needs for industrialization
Available routine training by IAPPI								IAPPI facilitation of developing precast concrete systems
Ministerial regulation support								Indonesian National Standard support
Ministerial regulation support								Higher needs for industrialization
Ministerial regulation support								IAPPI facilitation of developing precast concrete systems
Indonesian National Standard support								Higher needs for industrialization
Indonesian National Standard support								IAPPI facilitation of developing precast concrete systems
Higher needs for industrialization								IAPPI facilitation of developing precast concrete systems

According to the answer for opportunity factors, which sustainability criteria is more important?

	Sustainability criteria under Opportunity category							
	← MORE—— Comparison Levels ——MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Technical quality								Implementation and Enforcement

D. Pairwise comparison under Threat category

Under threat divided into three sustainability criteria namely **Social equity and culture, technical quality and Implementation and enforcement.** Please rank the relative importance of pairs under each sustainability category.

Which of the following factors do you think is more important?

	Threats							
	← MORE — Comparison Levels — MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Aver age**	**Strong**	**Very strong**	**Factor**
Social equity and culture								
Foreman-handyman culture difficult to change								Limited public awareness
Foreman-handyman culture difficult to change								Development centralized in Java Island
Foreman-handyman culture difficult to change								Shortage of expertise and skilled labor
Limited public awareness								Development centralized in Java Island
Limited public awareness								Shortage of expertise and skilled labor
Development centralized in Java Island								Shortage of expertise and skilled labor
Technical Quality								
Differences in quality and quantity of materials								
Implementation and Enforcement								
Lack of integrated standardization								Lack of government incentives, directives and promotion
Lack of integrated standardization								Road and bridge restrictions
Lack of government incentives, directives and promotion								Road and bridge restrictions

According to the answer for threat factors, which sustainability criteria is more important?

	Sustainability criteria under Threat category							
	← MORE — Comparison Levels — MORE →							
Factor	**Very strong**	**Strong**	**Aver age**	**Equal**	**Avera ge**	**Strong**	**Very strong**	**Factor**
Social equity and culture								Technical quality
Social equity and culture								Implementation and enforcement
Technical quality								Implementation and enforcement

4. Please state any other relevant points which have not been mentioned anywhere in this questionnaire.

APPENDIX C

Detail calculation of Data Analysis

Rating Scale Data

Code	Respondent																																		
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
S.EV.1	5	5	4	4	4	4	4	3	3	4	1	1	4	5	5	5	3	5	4	3	4	3	3	3	3	4	3	4	5	4	4	5	5	5	4	5
S.EV.2	4	5	3	4	4	5	4	5	3	4	5	5	2	5	5	5	5	4	4	4	3	4	4	5	4	5	4	4	5	5	4	3	4	5	4	5
S.EV.3	4	5	4	4	4	5	2	5	3	4	5	5	5	5	5	5	3	4	4	4	4	5	4	5	4	4	4	4	5	4	5	5	5	5	4	4
S.EV.4	5	4	4	5	5	5	4	5	3	4	5	5	5	5	5	5	5	4	4	4	5	4	4	5	5	5	4	5	5	5	3	5	5	5	4	5
S.EV.5	4	4	4	4	2	4	3	5	3	4	5	5	5	5	5	5	5	4	4	3	4	4	3	3	5	5	3	4	5	4	5	5	4	5	5	5
S.EV.6	5	5	3	3	5	4	3	5	2	2	5	5	5	5	5	5	4	5	3	3	5	4	4	3	4	5	4	5	5	3	4	5	5	5	3	5
S.EP.1	5	5	4	3	5	5	3	5	3	3	5	5	5	5	5	5	5	4	4	4	3	3	4	5	4	5	4	4	5	5	4	5	5	5	3	4
S.EP.2	5	5	4	4	4	4	3	5	3	3	5	5	4	5	5	5	5	5	3	4	5	3	3	4	5	5	4	4	5	5	4	4	5	5	4	4
S.SC.1	3	4	2	4	2	4	4	5	3	3	5	5	4	5	5	5	3	4	3	5	4	2	4	5	4	4	4	4	5	3	4	5	5	4	3	5
S.TQ.1	5	5	3	4	3	5	3	5	3	4	5	5	5	5	5	5	2	4	4	3	2	3	4	4	4	4	3	5	5	5	4	5	5	5	4	4
S.TQ.2	3	4	1	3	2	4	3	4	3	3	4	3	4	5	3	3	4	4	4	3	4	3	4	5	1	4	3	3	5	3	3	4	5	5	3	3
W.EV.1	5	4	4	5	3	4	4	5	3	4	5	1	2	5	3	5	3	3	3	3	4	4	3	5	5	3	4	3	2	4	4	5	3	5	3	3
W.EV.2	3	5	4	5	4	3	4	5	3	3	5	5	3	3	3	5	5	4	3	4	5	4	4	3	2	4	4	2	2	5	4	5	4	4	3	5
W.EV.3	2	5	3	2	4	3	4	3	3	3	2	2	2	4	3	3	2	3	3	4	5	3	4	5	1	2	4	4	5	5	3	4	4	4	3	4
W.EV.4	4	5	5	5	4	4	3	5	3	3	5	5	5	3	5	5	5	3	3	3	5	5	4	5	5	4	4	4	5	5	4	3	5	5	4	4
W.EV.5	3	5	4	5	4	4	4	5	3	4	5	5	5	5	5	5	5	5	4	4	5	5	4	5	4	5	5	4	5	5	4	5	5	5	4	5
W.TQ.1	3	5	4	4	5	3	3	3	3	3	5	5	2	4	3	3	2	4	3	4	5	3	3	3	5	5	5	4	3	5	4	5	4	4	4	3
W.TQ.2	3	4	4	5	5	2	4	5	2	2	5	5	2	3	3	1	5	4	3	3	4	4	2	5	5	4	3	3	1	4	4	4	5	4	3	4
W.TQ.3	3	4	3	5	3	4	4	5	3	3	5	5	3	5	2	1	3	4	3	3	5	4	4	5	5	5	4	4	5	5	4	5	4	5	4	5
O.TQ.1	4	4	3	3	5	2	1	5	3	3	2	5	5	4	5	5	3	4	3	4	4	5	4	5	5	5	4	4	5	5	4	5	5	5	3	5
O.IE.1	5	4	4	4	3	5	3	5	2	2	3	5	5	4	3	3	4	4	3	3	3	4	3	5	4	5	4	3	5	3	3	3	4	5	4	3
O.IE.2	4	4	4	5	4	5	3	5	3	3	3	5	5	4	4	3	3	5	4	3	3	5	4	5	3	5	4	1	5	4	4	5	3	5	3	4
O.IE.3	5	4	3	5	4	5	3	5	3	3	3	5	5	3	4	3	5	5	4	3	3	5	4	5	5	5	4	1	5	5	4	4	3	5	3	4
O.IE.4	4	4	4	4	4	5	4	5	3	4	4	5	5	3	4	3	3	4	3	4	5	4	4	3	5	5	4	3	5	5	4	4	4	5	2	4
O.IE.5	3	4	3	4	4	5	5	5	3	3	5	3	5	5	4	4	3	4	3	4	3	4	4	3	4	5	4	4	5	4	3	3	4	5	4	3
T.SC.1	5	2	5	4	3	3	5	5	2	2	5	5	4	4	5	5	2	5	3	3	4	2	4	5	2	4	4	3	5	3	3	3	4	5	4	5
T.SC.2	4	5	3	4	4	4	4	4	3	3	3	5	3	4	3	3	4	4	3	4	4	3	4	5	5	5	3	3	5	4	4	3	5	5	4	5
T.SC.3	3	4	4	4	3	3	4	4	4	4	5	2	2	4	2	3	2	5	3	3	4	4	4	5	1	4	4	4	1	4	4	5	3	4	4	5
T.SC.4	5	3	4	4	3	5	3	5	3	3	5	5	4	4	3	3	2	4	3	4	4	3	4	3	3	4	4	4	5	5	3	5	4	5	4	5
T.TQ.1	3	5	3	4	2	4	3	5	2	2	5	3	3	5	5	5	1	4	3	3	5	5	4	3	1	4	4	2	5	4	3	5	2	4	4	5
T.IE.1	4	2	3	4	3	4	3	5	3	3	5	1	2	3	5	5	4	4	3	2	4	3	3	3	5	3	4	3	5	4	4	4	4	4	4	5
T.IE.2	4	3	3	3	4	3	3	4	3	3	3	1	1	4	3	3	1	4	3	2	3	4	4	4	4	4	2	4	5	4	4	3	4	4	4	4
T.IE.3	5	3	4	4	2	5	4	5	3	4	3	5	3	4	2	3	1	5	3	2	5	4	4	4	1	3	3	4	4	4	3	4	4	4	4	5

Pairwise Comparison Data

Code			Respondent																																				Geometric Mean Method
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	
S.EV.1	or	S.EV.2		3	5	5	5	5	5	1	1	1	0.2	5		5			3	3	3	1	0.3	5	3		5	5	5	5			1		1	3	5	0.3	2.33
S.EV.1	or	S.EV.3		1	0.3	0.3	0.3	3	5	5	1	1	0.2	5		1			5	5	3	3	3	7	3		5	5	3	5			1		1	3	1	5	1.99
S.EV.1	or	S.EV.4		1	0.3	0.3	0.3	7	1	5	1	1	0.2	5		3			7	3	3	5	7	7	3		3	7	3	3			0.3		1	5	1	5	2.00
S.EV.1	or	S.EV.5		1	0.2	0.2	3	5	5	5	1	1	0.2	5		3			1	1	3	0.3	1	7	3		5	5	0.3	5			1		1	5	1	1	1.55
S.EV.1	or	S.EV.6		1	0.3	0.3	0.2	7	3	5	1	1	0.2	5		5			5	0.3	3	1	5	3	5		5	5	5	3			0.3		1	7	5	1	1.82
S.EV.2	or	S.EV.3		0.3	0.3	0.3	0.2	0.2	1	1	1	1	0.3	1		0.3			5	3	3	1	3	7	3		5	5	0.2	1			1		3	3	0.2	5	1.11
S.EV.2	or	S.EV.4		0.3	0.3	0.3	0.2	5	1	1	1	1	0.3	1		0.3			7	0.2	0.3	1	7	1	3		0.2	1	0.2	0.3			0.3		7	5	0.3	5	0.85
S.EV.2	or	S.EV.5		1	0.2	0.3	1	0.3	1	1	1	1	1	1		0.3			3	0.2	0.3	1	3	1	5		1	0.3	0.1	0.3			1		5	3	0.3	1	0.80
S.EV.2	or	S.EV.6		1	0.3	0.3	0.2	3	0.3	1	1	1	0.1	1		1			5	0.2	0.3	1	5	1	5		1	0.2	0.3	0.3			0.3		5	5	0.3	1	0.80
S.EV.3	or	S.EV.4		1	1	3	1	5	0.3	1	1	1	0.3	1		3			7	0.3	1	1	5	0.2	3		0.3	1	3	0.3			0.3		3	5	1	0.3	1.11
S.EV.3	or	S.EV.5		1	1	1	1	3	5	1	1	1	1	1		0.3			0.3	0.2	1	0.2	1	0.2	3		1	3	0.3	3			1		5	3	1	0.2	0.96
S.EV.3	or	S.EV.6		1	1	1	1	5	1	1	1	1	0.1	1		1			3	0.3	1	1	7	0.2	5		0.3	0.3	5	0.2			0.3		3	5	3	1	1.08
S.EV.4	or	S.EV.5		0.3	0.3	0.3	3	0.2	5	1	1	1	5	1		0.3			0.1	0.3	1	0.3	0.2	0.3	3		3	5	0.2	3			1		3	0.3	1	0.2	0.78
S.EV.4	or	S.EV.6		3	3	1	1	0.3	1	1	1	1	1	1		1			0.3	0.2	1	1	0.3	0.2	5		1	0.2	5	1			1		1	3	1	0.3	0.91
S.EV.5	or	S.EV.6		1	5	3	0.3	5	0.2	1	1	1	0.3	1		1			3	1	1	3	1	0.3	3		0.2	0.2	5	0.3			1		1	5	1	1	1.06
S.EP.1	or	S.EP.2	5	1	1	0.3	0.3	0.2	0.2	5	1	1	3	5	0.1	1	1	1	0.1	0.2	0.3	1	3	1	1	5	3	5	5	1	0.1	5	1	3	1	5	0.2	0.2	1.00
	S.SC.1																																						
S.TQ.1	or	S.TQ.2	5	1	3	1	0.3	0.2	1	1	1	1	0.3	1	0.2	1	1	1	0.2	5	3	1	5	1	1	0.2	0.1	0.2	5	0.2	1	0.2	1	1	1	0.2	1	0.2	0.76
S.EV	or	S.EP	3	1	3	3	3		1	0.3	1	1	3	1	0.3	1	0.3	0.3	7		0.3	1	3	0.2	1				0.3	0.3	0.3	0.3	1	0.3		5	0.2	1	0.87
S.EV	or	S.SC	3	1	5	3	3		1	0.2	1	1	0.3	1	0.2	1	0.2	0.2	1		0.3	0.3	0.3	0.1	3				0.2	0.2	0.2	1	1	0.3		3	0.2	0.2	0.61
S.EV	or	S.TQ	0.3	0.3	1	1	1		1	0.3	1	1	3	1	3	3	3	3	3		1	1	1	0.3	5				0.1	5	5	5	1	1		7	1	1	1.33
S.EP	or	S.SC	0.3	1	3	1	1		1	3	1	1	0.3	1	0.3	1	0.3	0.3	0.1		1	0.3	0.3	0.3	5				0.3	1	1	1	1	3		0.3	1	0.2	0.73
S.EP	or	S.TQ	0.2	1	0.3	1	1		3	3	1	1	3	1	5	1	5	5	0.1		3	1	1	5	5				0.2	5	5	5	1	3		5	5	1	1.67
S.SC	or	S.TQ	0.2	1	0.2	0.3	0.3		5	1	1	1	5	1	5	3	5	5	5		3	3	3	5	5				0.2	5	5	5	1	3		5	5	5	2.01
W.EV.1	or	W.EV.2		0.2	0.3	0.2	0.2	5	1	5	1	1	7				3	3	3	3	3	0.3	5	3	3	0.3	5	3		1	0.3		1	5	3	5	1	5	1.59
W.EV.1	or	W.EV.3		0.2	3	5	0.2	3	0.3	1	1	1	3				5	5	0.3	0.2	3	1	3	0.3	3	3	0.3	1		0.3	5		1	3	3	3	3	5	1.39
W.EV.1	or	W.EV.4		0.2	0.2	0.2	0.2	5	5	5	1	1	5				5	5	7	5	3	1	3	5	5	5	5	5		3	5		1	3	7	7	3	5	2.49
W.EV.1	or	W.EV.5		0.3	1	0.2	0.2	5	3	5	1	1	5				5	5	7	3	3	1	5	5	7	5	3	7		3	3		1	3	7	5	1	5	2.48
W.EV.2	or	W.EV.3		3	5	5	3	0.3	0.2	0.2	1	1	1				5	3	0.3	0.3	3	1	0.3	0.2	3	3	0.1	0.3		0.3	7		1	0.3	3	0.3	1	1	0.96
W.EV.2	or	W.EV.4		3	1	0.3	3	3	5	5	1	1	3				3	5	7	5	3	1	0.3	5	5	5	0.3	5		3	5		1	3	5	5	1	1	2.31
W.EV.2	or	W.EV.5		1	3	1	0.3	5	1	1	1	1	5				5	5	7	3	3	1	1	1	5	7	0.2	3		5	3		1	1	1	3	1	1	1.79
W.EV.3	or	W.EV.4		1	0.2	0.1	1	5	5	5	1	1	3				0.2	3	5	7	0.3	1	5	5	3	3	5	5		3	0.3		1	3	5	7	1	1	1.80
W.EV.3	or	W.EV.5		1	1	0.1	0.3	5	3	5	1	1	5				0.3	5	7	5	0.3	1	5	5	5	5	3	5		5	0.2		1	3	3	5	0.3	0.2	1.71
W.EV.4	or	W.EV.5		1	5	3	0.3	3	0.2	0.2	1	1	3				3	3	1	0.3	1	1	1	1	5	5	0.2	0.2		3	0.2		1	0.3	0.3	0.2	0.2	0.2	0.82
W.TQ.1	or	W.TQ.2	0.2	5		0.2	5	0.2	0.3	7	1	1	0.3	0.1	3		3	3	5		3	0.3	0.3	0.3	0.3	3		0.1	0.3	0.3	0.3		1	0.3	1	7	1	1	0.84
W.TQ.1	or	W.TQ.3	1	5		0.2	3	3	0.2	3	1	1	3	0.3	3		7	7	0.3		3	0.3	3	1	0.2	7		0.3	3	3	3		1	1	1	3	0.3	5	1.42
W.TQ.2	or	W.TQ.3	5	1		1	0.3	7	0.3	0.2	1	1	5	5	1		5	5	0.1		1	1	5	5	0.3	5		5	5	5	5		1	3	1	0.2	0.3	5	1.59
W.EV	or	W.TQ	1	1	1	0.3	0.3	5	5	5	1	1	5	1	0.3	1	1	1	0.1	5	3	0.3	0.3	5	3	5	0.2	0.3	3	0.3	1	1	1	1	0.3	5	3	1	1.15

Represent that the pairwise comparison consistency is above 0.1

Pairwise Comparison Data

Code			Respondent																																		Geometric Mean Method
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	
O.TQ.1																																							
O.IE.1	or	O.IE.2		1	3		0.3		1	0.2	1	1	0.1		1	5				3	3	1	5	3	3	1	3		0.2	1	7	1	1	3	1	3	3	1	1.37
O.IE.1	or	O.IE.3		1	3		5		1	0.2	1	1	0.2		1	0.5				3	3	1	5	3	5	1	7		0.3	3	5	5	1	3	1	5	1	1	1.60
O.IE.1	or	O.IE.4		1	0.3		3		0.3	1	1	1	0.2		1	3				7	1	1	5	3	5	1	7		0.2	3	5	5	1	5	3	5	1	1	1.63
O.IE.1	or	O.IE.5		1	3		0.3		1	3	1	1	0.3		1	1				3	3	1	1	1	7	1	7		3	1	3	1	1	1	1	7	1	1	1.44
O.IE.2	or	O.IE.3		1	1		5		3	3	1	1	3		1	0.2				0.3	1	1	0.3	1	3	1	7		5	0.3	0.3	5	1	0.3	0.3	5	1	5	1.25
O.IE.2	or	O.IE.4		1	0.3		5		1	5	1	1	5		1	1				5	0.3	1	0.3	1	3	3	7		0.3	1	0.2	1	1	3	1	3	0.3	5	1.30
O.IE.2	or	O.IE.5		1	5		3		5	5	1	1	5		1	0.2				0.5	1	1	0.2	1	5	1	3		5	0.3	0.2	1	1	0.3	3	5	0.3	1	1.23
O.IE.3	or	O.IE.4		0.3	0.3		0.3		1	5	1	1	3		1	1				5	0.3	1	3	1	3	5	1		0.2	3	0.3	1	1	3	3	0.3	0.3	1	1.08
O.IE.3	or	O.IE.5		0.3	3		0.2		3	5	1	1	5		1	1				3	1	1	1	1	5	3	1		3	0.3	0.2	0.2	1	0.3	3	3	0.3	1	1.12
O.IE.4	or	O.IE.5		3	5		0.3		5	1	1	1	3		1	1				0.2	3	1	0.3	1	5	0.2	0.2		7	0.3	0.3	0.2	1	0.3	1	5	1	1	0.99
O.TQ	or	O.IE	5	1	0.3	0.2	0.2	0.2	0.2	0.2	1	1	5	7	1	1	1	1	0.2	0.2	1	0.3	3	5	5	0.2	7	7	3	0.3	5	1	1	1	1	0.2	1	1	0.95
T.SC.1	or	T.SC.2	3	0.3	3	1	1		0.2		1	1	0.2	7	0.3	3	3	3	5	3	1	1	3	3	3	0.2	7	1	0.3	3	1		1	1	3	3	1	3	1.42
T.SC.1	or	T.SC.3	5	0.3	3	0.3	0.3		0.3		1	1	0.2	5	1	0.5	0.2	0.3	0.3	3	3	0.3	5	7	3	0.1	5	0.3	3	5	0.2		1	3	5	5	0.3	5	1.13
T.SC.1	or	T.SC.4	3	0.2	0.3	0.3	1		0.2		1	1	5	1	3	1	0.3	5	3	7	3	1	5	5	5	0.3	3	1	5	3	1		1	5	3	7	1	5	1.67
T.SC.2	or	T.SC.3	1	3	1	0.3	1		3		1	1	5	0.2	1	0.3	0.1	0.3	0.2	3	1	1	3	5	3	0.3	0.2	5	3	3	0.2		1	5	3	3	1	5	1.17
T.SC.2	or	T.SC.4	0.3	0.3	0.3	0.2	1		0.3		1	1	5	0.2	3	1	0.2	3	0.3	5	1	1	5	5	5	5	0.2	0.2	5	3	1		1	5	0.3	5	3	1	1.14
T.SC.3	or	T.SC.4	0.3	0.3	0.3	3	5		0.3		1	1	5	1	3	3	5	5	3	5	0.5	1	1	0.3	3	5	0.3	0.2	3	0.3	5		1	5	0.3	5	3	1	1.40
T.TQ.1																																							
T.IE.1	or	T.IE.2		1	0.2	0.2	0.2	7	7	1	1	1	0.3	7	1	0.3	0.3		0.3	3	0.2	1	1	0.3	3	0.3	0.3	5	0.3	0.3	0.3	3	1	0.2	0.3	0.3	0.3	0.2	0.68
T.IE.1	or	T.IE.3		1	1	0.3	3	5	5	5	1	1	3	3	1	0.2	3		0.1	0.3	0.3	1	5	1	7	0.1	0.2	1	0.2	1	0.1	0.3	1	0.2	0.3	0.2	0.3	1	0.79
T.IE.2	or	T.IE.3		1	5	3	7	0.3	0.3	5	1	1	5	0.2	1	0.3	5		0.2	0.2	3	1	5	5	5	0.2	0.3	0.2	0.3	3	0.2	0.2	1	1	1	0.3	1	5	1.01
T.SC	or	T.TQ	0.2	1	3	0.2	0.2	7	0.2	7	1	1	7		3		7	5	0.3	7	3	3	3	5	0.3	5	0.3	0.3	3	0.3	0.3	5	1	5	5	5	5	5	1.69
T.SC	or	T.IE	0.3	1	1	0.2	0.2	5	0.2	3	1	1	3		1		3	3	3	3	3	3	1	5	1	3	3	3	0.3	0.2	5	1	1	5	3	3	3	1	1.47
T.TQ	or	T.IE	3	1	0.3	1	1	0.3	1	0.2	1	1	0.2		0.3		0.2	0.3	5	0.2	1	1	0.3	1	3	0.3	5	5	0.2	0.3	7	0.2	1	1	0.3	0.3	1	0.2	0.70

Represent that the pairwise comparison consistency is above 0.1

Pairwise Comparison Analysis: Global Industry Perception to Strength and Weakness Category

STRENGTH

Economical Value	S.EV.1	S.EV.2	S.EV.3	S.EV.4	S.EV.5	S.EV.6
S.EV.1	1.00	0.43	0.50	0.50	0.65	0.55
S.EV.2	2.33	1.00	0.90	1.18	1.25	1.26
S.EV.3	1.99	1.11	1.00	0.90	1.04	0.93
S.EV.4	2.00	0.85	1.11	1.00	1.28	1.10
S.EV.5	1.55	0.80	0.96	0.78	1.00	0.94
S.EV.6	1.82	0.80	1.08	0.91	1.06	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.04	0.58	0.09	0.56		6.01
3.88	1.25	0.20	1.23		6.03
1.92	1.11	0.18	1.09		6.04
2.66	1.18	0.19	1.15		6.01
0.88	0.98	0.16	0.95		6.01
1.50	1.07	0.17	1.04		6.01
Total	6.17			λmax	6.02
				C.I	0.00
				C.R	0.00

Ecological Performance	S.EP.1	S.EP.2
S.EP.1	1.00	1.00
S.EP.2	1.00	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
1.00	1.00	0.50	1.00		2.00
1.00	1.00	0.50	1.00		2.00
Total	2.00			λmax	2.00
				C.I	0.00
				C.R	0.00

Technical Quality	S.TQ.1	S.TQ.2
S.TQ.1	1.00	1.32
S.TQ.2	0.76	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
1.32	1.15	0.57	1.14		2.00
0.76	0.87	0.43	0.86		2.00
Total	2.02			λmax	2.00
				C.I	0.00
				C.R	0.00

Sustainability Criteria	S.EV	S.EP	S.SC	S.TQ
S.EV	1.00	1.14	1.64	0.75
S.EP	0.87	1.00	1.38	0.60
S.SC	0.61	0.73	1.00	0.50
S.TQ	1.33	1.67	2.01	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
1.41	1.09	0.26	1.05		4.00
0.72	0.92	0.22	0.89		4.00
0.22	0.68	0.16	0.66		4.00
4.48	1.45	0.35	1.40		4.00
Total	4.15			λmax	4.00
				C.I	0.00
				C.R	0.00

WEAKNESS

Economical Value	W.EV.1	W.EV.2	W.EV.3	W.EV.4	W.EV.5
W.EV.1	1.00	0.63	0.72	0.40	0.40
W.EV.2	1.59	1.00	1.04	0.43	0.56
W.EV.3	1.39	0.96	1.00	0.56	0.58
W.EV.4	2.49	2.31	1.80	1.00	1.22
W.EV.5	2.48	1.79	1.71	0.82	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.07	0.59	0.11	0.55		5.01
0.40	0.83	0.15	0.78		5.02
0.43	0.85	0.16	0.79		5.01
12.61	1.66	0.31	1.55		5.02
6.24	1.44	0.27	1.34		5.00
Total	5.37			λmax	5.01
				C.I	0.00
				C.R	0.00

Technical Quality	W.TQ.1	W.TQ.2	W.TQ.3
W.TQ.1	1.00	1.19	0.71
W.TQ.2	0.84	1.00	0.63
W.TQ.3	1.42	1.59	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.84	0.94	0.31	0.92		3.00
0.53	0.81	0.26	0.79		3.00
2.26	1.31	0.43	1.28		3.00
Total	3.06			λmax	3.00
				C.I	0.00
				C.R	0.00

Sustainability Criteria	S.EV	S.TQ
S.EV	1.00	0.87
S.TQ	1.15	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.87	0.93	0.47	0.93		2.00
1.15	1.07	0.53	1.07		2.00
Total	2.00			λmax	2.00
				C.I	0.00
				C.R	0.00

Pairwise Comparison Analysis: Global Industry Perception to Opportunity and Threat Category

OPPORTUNITY

Implementation and Enforcement	O.IE.1	O.IE.2	O.IE.3	O.IE.4	O.IE.5
O.IE.1	1.00	0.73	0.62	0.61	0.69
O.IE.2	1.37	1.00	0.80	0.77	0.81
O.IE.3	1.60	1.25	1.00	0.93	0.89
O.IE.4	1.63	1.30	1.08	1.00	1.01
O.IE.5	1.44	1.23	1.12	0.99	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.19	0.72	0.14	0.71		5.01
0.69	0.93	0.18	0.91		5.00
1.65	1.10	0.22	1.09		5.01
2.30	1.18	0.23	1.16		5.00
1.97	1.15	0.23	1.13		5.01
Total	5.08			λmax	5.01
				C.I	0.00
				C.R	0.00

Sustainability Criteria	O.TQ	O.IE
O.TQ	1.00	1.05
O.IE	0.95	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
1.05	1.02	0.51	1.02		2.00
0.95	0.98	0.49	0.98		2.00
Total	2.00			λmax	2.00
				C.I	0.00
				C.R	0.00

THREAT

Social Equity and Culture	T.SC.1	T.SC.2	T.SC.3	T.SC.4
T.SC.1	1.00	0.70	0.88	0.60
T.SC.2	1.42	1.00	0.86	0.88
T.SC.3	1.13	1.17	1.00	0.71
T.SC.4	1.67	1.14	1.40	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.37	0.78	0.19	0.77		4.01
1.07	1.02	0.25	1.01		4.03
0.94	0.99	0.24	0.98		4.03
2.65	1.28	0.31	1.26		4.01
Total	4.06			λmax	4.02
				C.I	0.01
				C.R	0.01

Implementation and Enforcement	T.IE.1	T.IE.2	T.IE.3
T.IE.1	1.00	1.47	1.26
T.IE.2	0.68	1.00	0.99
T.IE.3	0.79	1.01	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
1.85	1.23	0.40	1.22		3.00
0.67	0.88	0.29	0.87		3.00
0.80	0.93	0.31	0.92		3.00
Total	3.03			λmax	3.00
				C.I	0.00
				C.R	0.00

Sustainability Criteria	T.SC	T.TQ	T.IE
T.SC	1.00	0.59	0.68
T.TQ	1.69	1.00	1.43
T.IE	1.47	0.70	1.00

Multiply the row	n^{th} root	vector of priorities	new matrix		divided matrix
0.40	0.74	0.24	0.72		3.01
2.41	1.34	0.43	1.30		3.01
1.03	1.01	0.33	0.98		3.01
Total	3.09			λmax	3.01
				C.I	0.00
				C.R	0.00

AHP Result: Global Industry

Sustainability Criteria	Local weights	Code	Factors	Local weights	Global weights
Economical Value	0.262	S.EV.1	Smaller on-site area and staging space required	0.09	0.025
		S.EV.2	More simplicity	0.20	0.053
		S.EV.3	Work in parallel	0.18	0.047
		S.EV.4	Less scaffolding and formwork	0.19	0.050
		S.EV.5	More success in meeting quality specifications	0.16	0.042
		S.EV.6	Less labor required	0.17	0.045
Ecological Performance	0.222	S.EP.1	More efficient material usage	0.50	0.111
		S.EP.2	Cleaner construction sites	0.50	0.111
Social Equity and Culture	0.165	S.SC.1	Greater job security	1.00	0.165
Technical Quality	0.350	S.TQ.1	More highly durable buildings	0.57	0.199
		S.TQ.2	Compensation for earthquake reduction factor	0.43	0.151
Economical Value	0.466	W.EV.1	Repetitious designs	0.11	0.051
		W.EV.2	Higher transportation costs	0.15	0.072
		W.EV.3	Licensing fees	0.16	0.073
		W.EV.4	Higher initial investments	0.31	0.144
		W.EV.5	Heavy equipment dependent	0.27	0.125
Technical Quality	0.534	W.TQ.1	More complex connection designs	0.31	0.165
		W.TQ.2	Greater loading difficulties for big components or long spans	0.26	0.141
		W.TQ.3	Greater difficulties in making changes during construction	0.43	0.229
Technical Quality	0.512	O.TQ.1	Availability of equipment	1.00	0.512
Implementation and Enforcement	0.488	O.IE.1	Available routine training by IAPPI	0.14	0.069
		O.IE.2	Ministerial regulation support	0.18	0.089
		O.IE.3	Indonesian National Standard support	0.22	0.106
		O.IE.4	Higher needs for industrialization	0.23	0.113
		O.IE.5	IAPPI facilitation of developing precast concrete systems	0.23	0.110
Social Equity and Culture	0.239	T.SC.1	Foreman-handyman culture difficult to change	0.19	0.046
		T.SC.2	Limited public awareness	0.25	0.060
		T.SC.3	Development centralized in Java Island	0.24	0.058
		T.SC.4	Shortage of expertise and skilled labor	0.31	0.075
Technical Quality	0.434	T.TQ.1	Differences in quality and quantity of materials	1.00	0.434
Implementation and Enforcement	0.327	T.IE.1	Lack of integrated standardization	0.40	0.132
		T.IE.2	Lack of government incentives, directives and promotion	0.29	0.094
		T.IE.3	Road and bridge restrictions	0.31	0.100

AHP Result: Government

Sustainability Criteria	Local Weights	Code	Factors	Local Weights	Global Weights
Economical Value	0.229	S.EV.1	Smaller on-site area and staging space required	0.14	0.031
		S.EV.2	More simplicity	0.32	0.073
		S.EV.3	Work in parallel	0.14	0.033
		S.EV.4	Less scaffolding and formwork	0.14	0.032
		S.EV.5	More success in meeting quality specifications	0.12	0.028
		S.EV.6	Less labor required	0.14	0.032
Ecological Performance	0.248	S.EP.1	More efficient material usage	0.56	0.139
		S.EP.2	Cleaner construction sites	0.44	0.109
Social Equity and Culture	0.216	S.SC.1	Greater job security	1.00	0.216
Technical Quality	0.306	S.TQ.1	More highly durable buildings	0.50	0.153
		S.TQ.2	Compensation for earthquake reduction factor	0.50	0.153

Economical Value	0.486	W.EV.1	Repetitious designs	0.19	0.092
		W.EV.2	Higher transportation costs	0.13	0.065
		W.EV.3	Licensing fees	0.31	0.152
		W.EV.4	Higher initial investments	0.17	0.085
		W.EV.5	Heavy equipment dependent	0.19	0.092
Technical Quality	0.514	W.TQ.1	More complex connection designs	0.41	0.211
		W.TQ.2	Greater loading difficulties for big components or long spans	0.27	0.139
		W.TQ.3	Greater difficulties in making changes during construction	0.32	0.164

Technical Quality	0.552	O.TQ.1	Availability of equipment	1.00	0.552
Implementation and Enforcement	0.448	O.IE.1	Available routine training by IAPPI	0.18	0.082
		O.IE.2	Ministerial regulation support	0.19	0.087
		O.IE.3	Indonesian National Standard support	0.23	0.105
		O.IE.4	Higher needs for industrialization	0.16	0.074
		O.IE.5	IAPPI facilitation of developing precast concrete systems	0.22	0.101

Social Equity and Culture	0.258	T.SC.1	Foreman-handyman culture difficult to change	0.25	0.063
		T.SC.2	Limited public awareness	0.29	0.076
		T.SC.3	Development centralized in Java Island	0.19	0.049
		T.SC.4	Shortage of expertise and skilled labor	0.27	0.070
Technical Quality	0.439	T.TQ.1	Differences in quality and quantity of materials	1.00	0.439
Implementation and Enforcement	0.302	T.IE.1	Lack of integrated standardization	0.45	0.136
		T.IE.2	Lack of government incentives, directives and promotion	0.20	0.060
		T.IE.3	Road and bridge restrictions	0.35	0.106

AHP Result: Manufacturer

Sustainability Criteria	Local Weights	Code	Factors	Local weights	Global weights
Economical Value	0.329	S.EV.1	Smaller on-site area and staging space required	0.08	0.026
		S.EV.2	More simplicity	0.24	0.080
		S.EV.3	Work in parallel	0.21	0.069
		S.EV.4	Less scaffolding and formwork	0.17	0.055
		S.EV.5	More success in meeting quality specifications	0.16	0.052
		S.EV.6	Less labor required	0.14	0.047
Ecological Performance	0.212	S.EP.1	More efficient material usage	0.39	0.083
		S.EP.2	Cleaner construction sites	0.61	0.129
Social Equity and Culture	0.173	S.SC.1	Greater job security	1.00	0.173
Technical Quality	0.286	S.TQ.1	More highly durable buildings	0.54	0.155
		S.TQ.2	Compensation for earthquake reduction factor	0.46	0.132
Economical Value	0.487	W.EV.1	Repetitious designs	0.16	0.077
		W.EV.2	Higher transportation costs	0.14	0.068
		W.EV.3	Licensing fees	0.15	0.071
		W.EV.4	Higher initial investments	0.31	0.149
		W.EV.5	Heavy equipment dependent	0.25	0.122
Technical Quality	0.513	W.TQ.1	More complex connection designs	0.33	0.171
		W.TQ.2	Greater loading difficulties for big components or long spans	0.17	0.086
		W.TQ.3	Greater difficulties in making changes during construction	0.50	0.256
Technical Quality	0.337	O.TQ.1	Availability of equipment	1.00	0.337
Implementation and Enforcement	0.663	O.IE.1	Available routine training by IAPPI	0.15	0.097
		O.IE.2	Ministerial regulation support	0.22	0.144
		O.IE.3	Indonesian National Standard support	0.27	0.177
		O.IE.4	Higher needs for industrialization	0.19	0.127
		O.IE.5	IAPPI facilitation of developing precast concrete systems	0.18	0.118
Social Equity and Culture	0.334	T.SC.1	Foreman-handyman culture difficult to change	0.20	0.067
		T.SC.2	Limited public awareness	0.22	0.073
		T.SC.3	Development centralized in Java Island	0.33	0.110
		T.SC.4	Shortage of expertise and skilled labor	0.25	0.084
Technical Quality	0.323	T.TQ.1	Differences in quality and quantity of materials	1.00	0.323
Implementation and Enforcement	0.343	T.IE.1	Lack of integrated standardization	0.41	0.141
		T.IE.2	Lack of government incentives, directives and promotion	0.34	0.118
		T.IE.3	Road and bridge restrictions	0.24	0.083

AHP Result: Contractor

Sustainability Criteria	Local weights	Code	Factors	Local weights	Global weights
Economical Value	0.191	S.EV.1	Smaller on-site area and staging space required	0.07	0.013
		S.EV.2	More simplicity	0.09	0.017
		S.EV.3	Work in parallel	0.18	0.034
		S.EV.4	Less scaffolding and formwork	0.32	0.061
		S.EV.5	More success in meeting quality specifications	0.12	0.023
		S.EV.6	Less labor required	0.23	0.043
Ecological Performance	0.235	S.EP.1	More efficient material usage	0.53	0.125
		S.EP.2	Cleaner construction sites	0.47	0.111
Social Equity and Culture	0.106	S.SC.1	Greater job security	1.00	0.106
Technical Quality	0.467	S.TQ.1	More highly durable buildings	0.50	0.234
		S.TQ.2	Compensation for earthquake reduction factor	0.50	0.234

Economical Value	0.455	W.EV.1	Repetitious designs	0.06	0.028
		W.EV.2	Higher transportation costs	0.11	0.048
		W.EV.3	Licensing fees	0.12	0.053
		W.EV.4	Higher initial investments	0.29	0.134
		W.EV.5	Heavy equipment dependent	0.42	0.191
Technical Quality	0.545	W.TQ.1	More complex connection designs	0.21	0.117
		W.TQ.2	Greater loading difficulties for big components or long spans	0.30	0.166
		W.TQ.3	Greater difficulties in making changes during construction	0.48	0.263

Technical Quality	0.575	O.TQ.1	Availability of equipment	1.00	0.575
Implementation and Enforcement	0.425	O.IE.1	Available routine training by IAPPI	0.08	0.033
		O.IE.2	Ministerial regulation support	0.20	0.085
		O.IE.3	Indonesian National Standard support	0.13	0.055
		O.IE.4	Higher needs for industrialization	0.39	0.164
		O.IE.5	IAPPI facilitation of developing precast concrete systems	0.21	0.088

Social Equity and Culture	0.177	T.SC.1	Foreman-handyman culture difficult to change	0.16	0.029
		T.SC.2	Limited public awareness	0.25	0.045
		T.SC.3	Development centralized in Java Island	0.14	0.025
		T.SC.4	Shortage of expertise and skilled labor	0.45	0.079
Technical Quality	0.490	T.TQ.1	Differences in quality and quantity of materials	1.00	0.490
Implementation and Enforcement	0.333	T.IE.1	Lack of integrated standardization	0.36	0.120
		T.IE.2	Lack of government incentives, directives and promotion	0.31	0.104
		T.IE.3	Road and bridge restrictions	0.33	0.109

AHP Result: Consultant/Designer

Sustainability Criteria	Local weights	Code	Factors	Local weights	Global weights
Economical Value	0.325	S.EV.1	Smaller on-site area and staging space required	0.08	0.025
		S.EV.2	More simplicity	0.14	0.044
		S.EV.3	Work in parallel	0.18	0.059
		S.EV.4	Less scaffolding and formwork	0.20	0.066
		S.EV.5	More success in meeting quality specifications	0.21	0.067
		S.EV.6	Less labor required	0.20	0.063
Ecological Performance	0.195	S.EP.1	More efficient material usage	0.53	0.104
		S.EP.2	Cleaner construction sites	0.47	0.091
Social Equity and Culture	0.136	S.SC.1	Greater job security	1.00	0.136
Technical Quality	0.344	S.TQ.1	More highly durable buildings	0.70	0.240
		S.TQ.2	Compensation for earthquake reduction factor	0.30	0.104

Economical Value	0.435	W.EV.1	Repetitious designs	0.07	0.030
		W.EV.2	Higher transportation costs	0.20	0.089
		W.EV.3	Licensing fees	0.10	0.044
		W.EV.4	Higher initial investments	0.41	0.179
		W.EV.5	Heavy equipment dependent	0.21	0.093
Technical Quality	0.565	W.TQ.1	More complex connection designs	0.28	0.158
		W.TQ.2	Greater loading difficulties for big components or long spans	0.33	0.185
		W.TQ.3	Greater difficulties in making changes during construction	0.39	0.222

Technical Quality	0.610	O.TQ.1	Availability of equipment	1.00	0.610
Implementation and Enforcement	0.390	O.IE.1	Available routine training by IAPPI	0.14	0.053
		O.IE.2	Ministerial regulation support	0.13	0.051
		O.IE.3	Indonesian National Standard support	0.20	0.077
		O.IE.4	Higher needs for industrialization	0.26	0.103
		O.IE.5	IAPPI facilitation of developing precast concrete systems	0.27	0.104

Social Equity and Culture	0.189	T.SC.1	Foreman-handyman culture difficult to change	0.15	0.027
		T.SC.2	Limited public awareness	0.22	0.041
		T.SC.3	Development centralized in Java Island	0.33	0.062
		T.SC.4	Shortage of expertise and skilled labor	0.31	0.058
Technical Quality	0.503	T.TQ.1	Differences in quality and quantity of materials	1.00	0.503
Implementation and Enforcement	0.308	T.IE.1	Lack of integrated standardization	0.38	0.116
		T.IE.2	Lack of government incentives, directives and promotion	0.32	0.097
		T.IE.3	Road and bridge restrictions	0.31	0.095

APPENDIX D

Upper Critical Values of the Chi-Square Distribution

Upper Critical Values of the Chi-Square Distribution

df	Probability under H_0 that $\chi^2 \geq X^2$				
	0.100	0.050	0.025	0.010	0.001
1	2.706	3.841	5.024	6.635	7.879
2	4.605	5.991	7.378	9.210	10.597
3	6.251	7.815	9.348	11.345	12.838
4	7.779	9.488	11.143	13.277	14.860
5	9.236	11.070	12.833	15.086	16.750
6	10.645	12.592	14.449	16.812	18.548
7	12.017	14.067	16.013	18.475	20.278
8	13.362	15.507	17.535	20.090	21.955
9	14.684	16.919	19.023	21.666	23.589
10	15.987	18.307	20.483	23.209	25.188
11	17.275	19.675	21.920	24.725	31.264
12	18.549	21.026	23.337	26.217	32.910
13	19.812	22.362	24.736	27.688	34.528
14	21.064	23.685	26.119	29.141	36.123
15	22.307	24.996	27.488	30.578	37.697
16	23.542	26.296	28.845	32.000	39.252
17	24.769	27.587	30.191	33.409	40.790
18	25.989	28.869	31.526	34.805	42.312
19	27.204	30.144	32.852	36.191	43.820
20	28.412	31.410	34.170	37.566	45.315
21	29.615	32.671	35.479	38.932	46.797
22	30.813	33.924	36.781	40.289	48.268
23	32.007	35.172	38.076	41.638	49.728
24	33.196	36.415	39.364	42.980	51.179
25	34.382	37.652	40.646	44.314	52.620
26	35.563	38.885	41.923	45.642	54.052
27	36.741	40.113	43.195	46.963	55.476
28	37.916	41.337	44.461	48.278	56.892
29	39.087	42.557	45.722	49.588	58.301
30	40.256	43.773	46.979	50.892	59.703

Source: Siegel and Castellan, 1988

VITA

Joan Kartini Rossi was born in Las Cruces, New Mexico, United States on 30th May 1990. She completed her Junior High at SMPN 30 Jakarta Utara in 2005 and Senior High at SMAN 8 Jakarta Selatan in 2008. She fulfilled her Bachelor Degree in Civil and Environmental Engineering at Institut Pertanian Bogor (IPB) in 2012. She was then awarded Scholarship for Neighboring Countries from Chulalongkorn University, Thailand to pursue her master Degree in Construction Engineering and Management at Chulalongkorn University, Thailand.

During her study at IPB, she was a teaching assistant for Hydraulics Structures and Fluid Mechanics subjects in Civil and Environmental Engineering Department. She had internship at Water Resources Research and Development, Ministry of Public Works and Human Settlement in 2011. After graduated from IPB, she continued to work at a construction company in DKI Jakarta as Planning and Monitoring staff in 2013.

She was active in student organization since Junior High School, such as Chairman of Class Representative Board of SMPN 30 Jakarta (2005), Vice Chairman of Class Representative Board of SMAN 8 Jakarta (2007), Founder and Chairman of Civil and Environmental Student Association of IPB (2009 – 2010), and Treasurer of Asean Community Department, Indonesian Student Association in Thailand (Permitha). Notable achievements during her study at IPB are Outstanding Academic Achievement at the Undergraduate Program (2009), Funded Research for “Program Kreativitas Mahasiswa Bidang Penelitian” held by Dikti (2011), Candidate of Outstanding Students of Faculty of Agricultural Technology, IPB (2011), and 1st winner Documentary Film held by Student Executive Board of Faculty of Agricultural Technology, IPB (2012). She has participated in International Conference of Architecture and Civil Engineering (ACE) 2015 in Singapore as Presenter of her paper entitled “Precast Load Bearing Wall for Low-Cost Housing: a SWOT Analysis in Indonesia”.