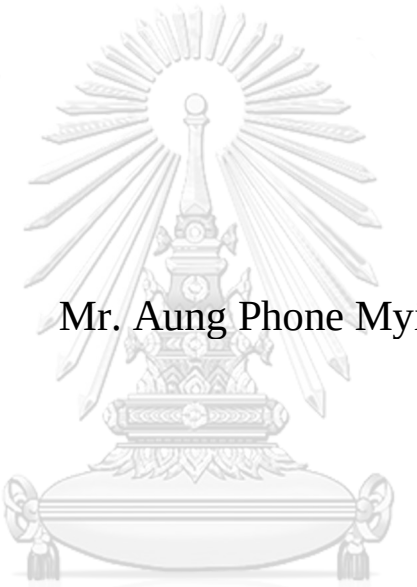
DEVELOPMENT OF A READINESS MODEL FOR THE APPLICATION OF PRECAST CONCRETE IN HOUSING CONSTRUCTION: A CASE STUDY IN MYANMAR

Mr. Aung Phone Myint



A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Civil Engineering
Department of Civil Engineering
FACULTY OF ENGINEERING
Chulalongkorn University
Academic Year 2019

การพัฒนาแบบจำลองเรดิเนส สำหรับการประยุกต์ใช้งานชิ้นส่วนคอนกรีตสำเร็จรูปในโครงการก่อสร้างบ้านพักอาศัย กรณีศึกษาในประเทศเมียนมา

นายออง โฟน มินท์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมโยธา ภาควิชาวิศวกรรมโยธา
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	DEVELOPMENT OF A READINESS MODEL FOR THE APPLICATION OF PRECAST CONCRETE IN HOUSING CONSTRUCTION: A CASE STUDY IN MYANMAR
By	Mr. Aung Phone Myint
Field of Study	Civil Engineering
Thesis Advisor	Associate Professor TANIT TONGTHONG, Ph.D.

Accepted by the FACULTY OF ENGINEERING, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Engineering

..... Dean of the FACULTY OF ENGINEERING
(Professor SUPOT TEACHAVORASINSKUN, Ph.D.)

THESIS COMMITTEE

..... Chairman
(Assistant Professor VACHARA PEANSUPAP, Ph.D.)
..... Thesis Advisor
(Associate Professor TANIT TONGTHONG, Ph.D.)
..... Examiner
(Associate Professor NOPPADON JOKKAW, Ph.D.)
..... External Examiner
(Assistant Professor Kongkoon Tochaiwat, Ph.D.)

ออง โฟน มินท์ : การพัฒนาแบบจำลองเรดิเนส สำหรับการประยุกต์ใช้งานชิ้นส่วนคอนกรีตสำเร็จรูปในโครงการก่อสร้างบ้านพักอาศัย กรณีศึกษาในประเทศเมียนมา. (DEVELOPMENT OF A READINESS MODEL FOR THE APPLICATION OF PRECAST CONCRETE IN HOUSING CONSTRUCTION: A CASE STUDY IN MYANMAR) อ.ที่ปรึกษาหลัก : รศ. ดร.ธนิต ธงทอง

การก่อสร้างด้วยระบบคอนกรีตสำเร็จรูปได้รับการพิสูจน์แล้วว่าเป็นหนึ่งในวิธีการสำหรับการพัฒนาที่อยู่อาศัยและการเจริญเติบโตของเขตเมือง อีกทั้งการใช้คอนกรีตสำเร็จรูปสามารถร่นระยะเวลาในการก่อสร้าง ลดความต้องการในการใช้แรงงาน และลดการสูญเสียวัสดุในการก่อสร้างได้ อย่างไรก็ตามการใช้เทคโนโลยีคอนกรีตสำเร็จรูปยังไม่เป็นที่นิยม และไม่ได้มีการใช้งานอย่างแพร่หลายในอุตสาหกรรมการก่อสร้างของประเทศเมียนมาร์ ยิ่งไปกว่านั้นในปัจจุบันยังไม่มีโมเดลสำหรับการประเมินความพร้อมของอุตสาหกรรมการก่อสร้างซึ่งประกอบไปด้วยผู้มีส่วนเกี่ยวข้องหลักอันเป็นตัวแทนของอุตสาหกรรมการก่อสร้างสำหรับการยอมรับเทคโนโลยีก่อสร้างใหม่ ๆ ดังเช่นคอนกรีตสำเร็จรูป จากที่กล่าวมาทำให้เกิดงานวิจัยฉบับนี้ซึ่งมีวัตถุประสงค์คือ เพื่อพัฒนาแบบจำลองสำหรับการประเมินความพร้อมของอุตสาหกรรมการก่อสร้างสำหรับการประยุกต์ใช้คอนกรีตสำเร็จรูปในการก่อสร้างที่พักอาศัย และเพื่อประเมินความพร้อมในการใช้งานคอนกรีตสำเร็จรูปในอุตสาหกรรมการก่อสร้างของประเทศไทยและประเทศเมียนมาร์ จากโครงการกรณีศึกษาที่ได้นำเอาเทคโนโลยีการก่อสร้างคอนกรีตสำเร็จรูปมาใช้ การสัมภาษณ์แบบ Semi-structure interview และแบบสอบสอบถามจะถูกนำมาประยุกต์ใช้กับการศึกษาครั้งนี้ ทั้งนี้งานวิจัยฉบับนี้สามารถสร้างคุณประโยชน์ได้ด้วยการสร้างแบบจำลองที่เรียกว่า แบบจำลองสำหรับการประเมินความพร้อมในการก่อสร้างด้วยคอนกรีตสำเร็จรูป (PCCRM) เพื่อให้วิธีการก่อสร้างโดยเทคโนโลยีคอนกรีตสำเร็จรูปเป็นที่ยอมรับในอุตสาหกรรมก่อสร้างมากขึ้น ทั้งนี้การประยุกต์ PCCRM นั้นจะไม่ถูกจำกัดเพียงอุตสาหกรรมก่อสร้างเท่านั้น แต่ยังสามารถนำไปใช้ในการประเมินความพร้อมในการใช้งานคอนกรีตสำเร็จรูปของผู้ที่เกี่ยวข้อง 4 ฝ่ายประกอบด้วย ผู้รับเหมา ผู้พัฒนาโครงการ ผู้บัญญัติกฎหมาย และ กลุ่มลูกค้า ซึ่งผลของการใช้ PCCRM กับโครงการที่เป็นกรณีศึกษาทำให้ทราบถึงความเป็นไปในปัจจุบันของการใช้คอนกรีตสำเร็จรูปในประเทศไทยและประเทศเมียนมาร์ ยิ่งไปกว่านั้นการประยุกต์ใช้แบบจำลองนี้จะช่วยสร้างแนวทางสำหรับผู้มีส่วนเกี่ยวข้องที่ซึ่งปัจจุบันมีการประยุกต์ใช้เทคโนโลยีคอนกรีตสำเร็จรูปหรือมีแนวโน้มที่จะใช้เทคโนโลยีคอนกรีตสำเร็จรูปในอนาคต เพื่อให้การใช้งานเทคโนโลยีคอนกรีตสำเร็จรูปมีประสิทธิภาพ ประสบความสำเร็จตามเป้าหมาย ซึ่งโครงการที่นำมาศึกษาในงานวิจัยฉบับนี้จะมีลักษณะเป็นโครงสร้างการรับแรงประเภท load-bearing wall system และเป็นที่พักอาศัยประเภท low-rise จากผลการวิเคราะห์แบบจำลอง PCCRM สามารถสรุปได้ว่าอุตสาหกรรมการก่อสร้างของประเทศไทยมีความพร้อมและมีความสามารถในการประยุกต์ใช้เทคโนโลยีการก่อสร้างคอนกรีตสำเร็จรูปในอุตสาหกรรมก่อสร้างได้ ในขณะที่อุตสาหกรรมการก่อสร้างของประเทศเมียนมาร์ยังมีความจำเป็นที่จะต้องปรับปรุงในหลายประเด็น เพื่อให้มีความพร้อมสำหรับการก่อสร้างด้วยระบบคอนกรีตสำเร็จรูป

สาขาวิชา	วิศวกรรมโยธา	ลายมือชื่อนิสิต .....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

6170330321 : MAJOR CIVIL ENGINEERING
KEYWOR D: Precast concrete/ Readiness model/ Myanmar construction industry

Aung Phone Myint : DEVELOPMENT OF A READINESS MODEL FOR THE APPLICATION OF PRECAST CONCRETE IN HOUSING CONSTRUCTION: A CASE STUDY IN MYANMAR. Advisor: Assoc. Prof. TANIT TONGTHONG, Ph.D.

Precast concrete construction has been verified that it is one of the solutions for the growth of urbanization and housing development. In addition, it helps to reduce the labor requirement and material wastage in construction. However, the use of precast concrete technology is not still popular and not widely used within the Myanmar housing construction industry. Moreover, there is no readiness assessment model encompassed the readiness of construction industry including major stakeholders who are representatives of the construction industry for accepting the new technology. Therefore, the aim of this study is to develop a readiness model that can assess the readiness of the construction industry for the application precast concrete. In addition, a case study for readiness assessment in Thailand and Myanmar is conducted by using the proposed model. Semi-structure interview and questionnaire surveys are applied in this study. The main contribution of the research is the development of a readiness assessment model called ‘Precast Concrete Construction Readiness Model (PCCRM)'. The PCCRM model can be applied not only for the construction industry but also for self-assessment on four major stakeholders which are Contractor, Developer, Regulator and Customer to know the readiness in the use of precast concrete construction. And the results of the case studies provide knowledge on the current situation of precast concrete application, the drivers and barriers regarding the use of precast concrete construction in Thailand and Myanmar. Moreover, application of this model will help as a guideline for stakeholders to achieve successful adoption of the technology. The type of precast concrete construction conducted in this study is specifically referred to precast load-bearing wall system and the focused projects are low rise housing projects. This study concludes that Thailand construction industry are ready and capable to adopt the precast concrete construction while Myanmar construction industry requires improvements in several areas to achieve readiness level for the adoption of precast concrete construction.

Field of Study:	Civil Engineering	Student's Signature .....
Academic Year:	2019	Advisor's Signature .....

ACKNOWLEDGEMENTS

Firstly, I would like to express my deep and sincere gratitude to my research advisor, Associate Professor Dr. Tanit Tongthong for his encouragement, patience, continuous supports, invaluable guidance, recommendations and as well as critical advices along the way of conducting the research. It was a great privilege and honor to be his advisee and study under his guidance.

I am also deeply grateful and would like to express thanks to my research committee, Assistant Professor Dr. Vachara Pensupap who is committee chairperson, Associate Professor Dr. Noppadon Jokkaw who is internal examiner and Assistant professor Dr. Kongkoon Tochaiwat who is external examiner for their helpful and effective ideas, suggestions and recommendations which make to become a good research.

I would like to express profound thanks to Siam Cement Group (SCG) Myanmar for its financial support, my boss, Mr. Sorasak Keeratichokechaikul and management team for offering the scholarship to study master's degree at Chulalongkorn University. Besides, special thanks to my mentors who are from CPAC Post-tension Department for their supports and helps while studying in Thailand.

I am extremely grateful to all the specialists from Thailand and participants from Myanmar who shared their time and experiences for my research. And I also thank all my seniors, juniors and friends as well as fellows in Chulalongkorn University for their supports and helps during the study time.

Finally, I would like to express my heartfelt thanks to my beloved family: my father, U Tin Htwe, my mother, Daw Hla Htwe and my brothers for their great encouragements, loves, care and supports. Besides, special thanks go to all my teachers who I met along the way of my life.

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INTRODUCTION

1.1 Background of Research

Myanmar is one of the developing countries in the world and the population is about 54 million. Nay Pyi Taw is the country's capital city, and Yangon is the largest city (the commercial center) with over 7 million people. The country re-opened its economy in 2011 after transforming into a "discipline-flourishing democracy" country from a communist country. Then, the government tried to develop the economy of the country, but the Myanmar's economy is still in initial stage, being one of the weak economic countries in Southeast Asia. In addition, GDP per capita of 2017-2018 was lowest among the Southeast Asia countries (PWC_Myanmar, 2018).

However, the low GDP figures imply a potential for economic growth as it pushes to catch up with other strong economic countries. The government efforts for economy grow, increasing foreign investments in Myanmar and China's Belt and Road Initiative (BRI) are expected to drive the country's economy. Along with those, the overall economy and GDP of the country are expected to grow. Figure 1.1 shows Myanmar's overall GDP of the country.

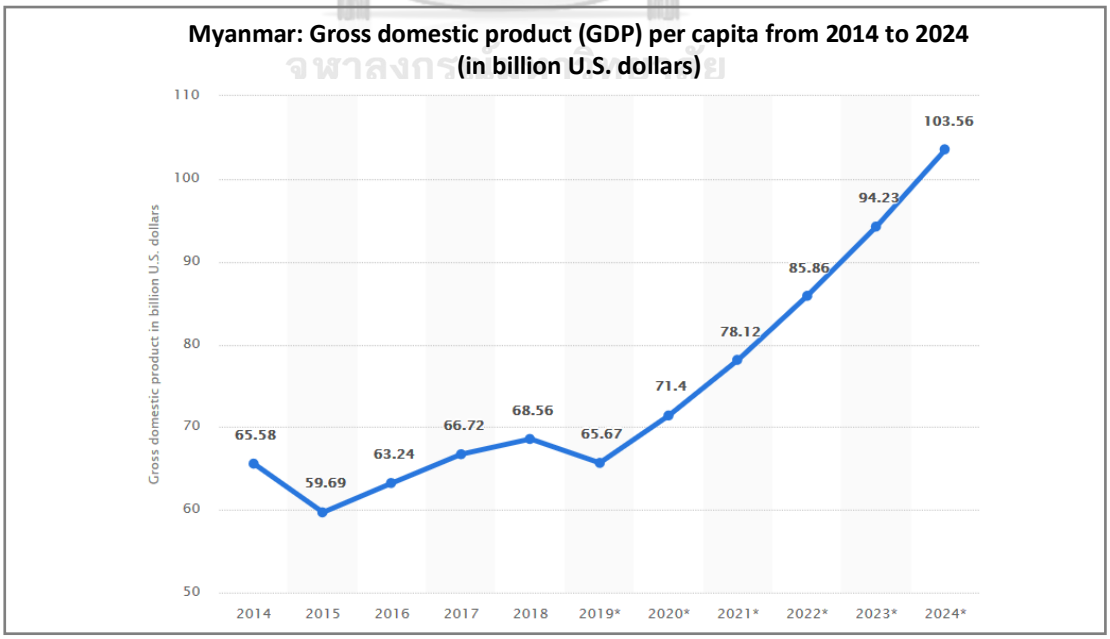

Figure 1.1: Myanmar Gross Domestic Product

Nowadays, the construction industry is one of the sectors that is important for every nation's economy and development. According to Myanmar_Builder_Guide (2018), since the government has opened wider doors for oversea companies to conduct the business in Myanmar, the construction industry becomes a key driver of Myanmar's economy. In 2018, the value of construction industry was more than 9.5 billion US dollar. This amount is around 16.5 percent share of the country's GDP (ASEAN_Briefing, 2019).

In Myanmar, there are tremendous opportunities for real estate, building materials and construction business along with the growth of economic. According to statistics in 2014, residential and infrastructure sectors took 80% of overall Myanmar's construction industry while industrial and commercial sectors accounted for 14% and 6%, respectively (Myanmar_Builder_Guide, 2018).

As urban development plan, the Ministry of Construction (MOC) is planning to construct more than one million apartments in 330 townships all over the country by 2030. MOC declared a five-year housing development plan (FY 2017-2021) which is to build 180,000 apartments around the county.

According to Consulting (2013), increasing urbanization in metropolis will be one of the major impacts on the growth of Myanmar's construction industry. Now 7.4 million people are living in Yangon city, and it is forecasted that by 2040 Yangon will be one of the mega cities around the world with over 10 million people population. Approximately 32% of Myanmar's population lives in metropolitan areas with an urbanization rate of 2.4% per annum that is estimated through 2015. Moreover, half the population of the country will be city dwellers by 2031.

In addition, the Department of Urban and Housing Development (DUHD) deputy director revealed that the requirement of housing would follow the growth of population over the next 20 years. DUHD predicted that by 2040 an additional 4.8 million housing units would be required for an estimated population over 70 million people in Myanmar, and over 22 percent or 1.07 million housing units would be Yangon dwellers. To fulfill the housing requirement of Myanmar people, the DUHD has planned to supply 20 percent of that required amount of housing units. Among

these 20 percent, 90 percent of the housing units will be for low-income citizens while the remaining 10 percent will go to middle-income citizens. For the remaining 80 percent of housing needs, DUHD makes private companies to implement those and it will be affordable housings. Moreover, in Myanmar, the government allowed private sector participation in construction industry since 1990. Therefore, these are big opportunity for foreign and local investors in Myanmar housing construction industry (THE_NATION_THAILAND, 2018).

Private companies are also expected to take on the bulk of affordable housing projects. Executive committee of Myanmar Construction Entrepreneurs Association announced that they would commence a three-year project this year, worth $200 million. The project is expected to supply 20,000 housing units by 2020. Moreover, four new mega-projects will also be implemented by the DUHD using public-private partnership (PPP) schemes: The New Mandalay Resort city project, Eco Green City and Korea/Myanmar industrial complex projects and Yangon's "Smart District" project (Mingalar, 2018).

The above information implies that Myanmar construction industry is required to fulfill the growth of urbanization and housing development on time. On the other hand, it should be noted that achieving targeted quality, speed and project management skills in construction may be another challenges while accomplishing housing requirements (Arif, Goulding, & Rahimian, 2012). To overcome the challenges, the industry should adopt the alternative technologies used around the world. Among those technologies, precast concrete technology is one of the potential alternatives to traditional construction methods.

1.2 Statement of Research Problem

Precast concrete technology is one of the construction technologies recognized worldwide because it offers significant advantages such as easier and quicker construction for the building, lower overall cost of the project, better quality and durability of the materials, less buidling materials wastage, better sustainability and better occupational health and safety (Polat, 2008). Moreover, based on Turai and Waghmare (2015), the application of precast concrete technique enhanced work quality, time-saving and cost-saving required for maintenance of work.

In Myanmar, most of the housing construction projects are built by RC frame systems as traditional construction methods (cast in place construction) to implement the project and it is rarely to see the projects that are applied precast concrete method in housing construction. Although the traditional method is a good construction method, there are many weak points when compared with other alternative methods. For instance, the weak points of the traditional method are long construction time, the requirement of a large number of labors, poor quality and cost uncertainty. In addition, some of the contractors in Myanmar have been suffering losing profit because of cost overrun, delay in completion and quality deviation in their construction projects. Especially, delaying projects are highly effected to be cost overrun since the interest rate for borrowing money from the bank in Myanmar is very high (13% per annual). In addition, Myanmar's construction industry is facing the problems to obtain skilled labors sufficiently for construction projects as the country attracts more investments (MYANMAR_TIME, 2017). Moreover, as mentioned in the section 1.1, Myanmar construction industry requires to facilitate the growth of urbanization and housing development with challenges in achieving required quality and speed in construction.

On the other hand, many studies reveal that the application of precast concrete can offer many benefits for the construction industry. Ting, Charnwasununth, and Peansupap (2019) presented that using precast concrete can attain overall cost saving as less labor requirement, less maintenance cost, less material wastage in the construction, cost certainty and time saving. Besides, according to Jaillon and Poon (2008), the application of precast concrete construction can get high-quality control and assurance because precast concrete components are manufactured in a factory environment and they are checked before transporting to the site. In addition, Goodier and Gibb (2007) mentioned that the application of the precast concrete system was an ideal solution to solve the lack of skilled worker problems in the construction industry. However, in Myanmar, awareness and adoption of a precast concrete system are very low and there are very few numbers of buildings that are using the precast concrete system.

Therefore, the present situation of growing demand for urbanization and housing development, shortage of skilled labors, obtaining target profit and challenges of achieving designed quality and speed in construction in Myanmar can be aware as the adoption of a precast concrete system is one of the solutions to solve these problems. Regarding the adoption of new technology or system, Keupp and Gassmann (2013) stressed that it was essential to compare and check the current knowledge or practices within an organization before adoption any new technology and innovation. Therefore, evaluating the readiness for the adoption of the precast concrete system is essential to improve the weak points of the organization or construction industry before the adoption of the precast concrete system.

To evaluate the readiness for the application of precast concrete construction in Myanmar, this research conducts an intensive literature review to find the readiness model. Many researchers generated readiness models, framework and tools in order to support the adoption and implementation of new systems and technology and to assist in determining its readiness level for application. However, most of existing readiness models, framework and tools were developed for the application for software, e-commerce and other technologies, and they were not specifically developed for appliaction of precast concrete method. Moreover, most of them were made to assess the readiness of organization level only.

For instance, VERDICT was designed for end-users in the construction industry to determine the overall readiness of e-commerce technologies. The strength of the VERDICT model is that it is useful to measure the level of readiness not only for construction companies but also for departments within the company or even individual groups within the department (Aziz & Salleh, 2011). However, this model is specifically for the application of e-commerce technologies and it cannot assess for industry level. In addition, Khalfan, Anumba, and Carrillo (2001) developed BEACON (Benchmarking and Readiness Assessment for Concurrent Engineering in Construction) Model in order to evaluate the readiness level of implementing concurrent engineering in the construction industry. As it was specifically developed for the use of concurrent engineering in construction, it cannot be directly applied for the use of precast concrete construction.

Moreover, The offsite construction (OSC) readiness framework was developed to determine the preparation of the construction organization in Inda for the application of OSC method. By using the OSC readiness framework, the framwork provides the curent capability of the organization to implement OSC construction activities (Bendi, 2017). Although OSC readiness framework seems to be possible in order to use for readiness assessment of the precast concrete application, there are several weaknesses in this framewok. OSC framework is not covered to assess the readiness of construction industry including major stakeholders and the result from the framework can represent only for single organization. Moreover, it is difficult to conclude whether ready or not for the whole organization based on final result from the framework because it was designed to show the result only for each factor's readiness of the organization and it does not show overall readiness result for organization. Furthermore, Musa, Mohammad, Yusof, and Ahmad (2016) also developed the Industrialized Building System Modular System (IBSMS) organizational readiness framework to improve the Malaysian construction industry and to achieve better readiness for construction organizations which execute IBSMS in Malaysia. The study of this framwork identifed only the readiness factors and components for the application of IBSMS. Moreover, this framework was developed only for contractor and manufacturer, and it did not mention the methdology how to analyze in order to get the readiness level of an organiztion. Therefore, the framwork can not be directly applied to assess the readiness of the construction industy inclucing major stakeholders for the adoption of precast concrete method.

As discussed above, many researchers have been done worldwide in evaluating the readiness to support the adoption of new systems and technologies. Nevertheless, these can be used to assess the readiness only for single organization (only organization level) and it seems that so far, there is no readiness model or framework that covers to assess the readiness of construction industry for the application of precast concrete. In the construction industry, there are many stakeholders such as contractor, developer, regulator, customer, designer, manufacturer and etc. In addition, since the use of precast concrete method for housing is not very popular in Myanmar, it seems that there is very less research available on precast concrete construction in Myanmar.

Therefore, this research was aimed to fill the gap by developing a new readiness model that can assess the readiness of four major stakeholders (contractor, developer, regulator and customer) which are representatives of the construction industry in accepting of new technology. Through the model, it will give information about readiness of not only construction industry but also stakeholders. Moreover, the proposed model will also provide the readiness percentage of the stakeholders and construction industry with the new diagram for better understanding. Finally, application of this model would help as a guide for stakeholders which are presently applying, and which have plan to apply the precast concrete technology in order to prepare themselves to achieve successful adoption of the technology and business target.

1.3 Objective of Research

The aim of the research was to develop a new readiness model that can assess the readiness of the construction industry via four major stakeholders for the adoption of precast concrete construction. These four major stakeholders which are contractor, regulator (government), developer and customer (house buyer) are considered as representatives of the construction industry since they play the major roles in accepting the new technology such as precast concrete. And the readiness of these stakeholders for the application of new technology will reflect on the readiness of construction industry directly. Therefore, the readiness of construction industry is evaluated based on the readiness of the major stakeholders in this study.

The aim of this research could be accomplished by conducting the following objectives:

1. To investigate advantages, hindrances and the factors that influence the application of precast concrete construction through literature review for development of the model
2. To conceptualize a new readiness model to assess the application of precast concrete construction by exploring existing readiness assessment tools, models and framework from various industries

3. To assess the readiness of construction stakeholders and industry by measuring the maturity level for the adoption of precast concrete in housing construction projects.

1.4 Scope of Research

This study was mainly focused on developing a new readiness assessment model and evaluating the maturity level of construction industry for the application of precast concrete in housing sector. For this process, the investigated location was in Yangon, Myanmar and Bangkok, Thailand. The target groups were precast concrete experts and major stakeholders (customers, contractors, developers, and government) who involved in the housing construction industry. The type of precast concrete construction conducted in this study was specifically referred to precast load-bearing wall system and the focused project in this research was low rise housing project. Therefore, the meaning of the precast concrete system in this study was referred to precast load-bearing wall system for the low rise housing projects if it was not stated others.

1.5 Expected Contribution of the Research

The main contributions of this research were

- A new precast concrete construction readiness model which can assess the readiness of construction industry
- Providing the knowledge about advantages, hindrances and critical success factors of the precast concrete construction.
- Providing the information about the readiness level of the application of precast concrete construction in Myanmar and Thailand.

1.6 Outline of Research

This research was comprised of six chapters. Each chapter of the research is briefly discussed in this section as followed.

Chapter 1 presents justification of the research, background of research and statement of research problem in order to give the reasons of conducting this research.

Moreover, objective, scope and expected contribution of the research are explained for the research direction.

Chapter 2 is about reviewing the literatures to make sure the knowledge of current situation. This chapter gives information about overview, advantages, hindrances and critical factors of precast concrete. In addition, essential characteristics of precast concrete and market experience of precast concrete in other countries are described. Furthermore, the researcher focuses on the definition of readiness, maturity and readiness assessment models, tools and framework from various areas in this chapter.

Chapter 3 describes justification of research methodology and design applied for this research. This chapter reveals about tools and methods of data collection, data analysis and research framework.

Chapter 4 explains the development of precast concrete construction readiness model and there are two main parts in this chapter. In the first part, it describes development of conceptualized model based on literature reviews and comparison of readiness models, tools and frameworks. In the second part, validation of the conceptualized model is presented including the feedbacks from the interview with the experts. Moreover, this chapter describes the factors used in the model.

Chapter 5 discusses the readiness assessment results of case studies conducted for Thailand and Myanmar construction industries. This chapter gives information about existing readiness level of construction stakeholders and industry for the application of precast concrete construction in Thailand and Myanmar. Moreover, in order to achieve better readiness for the application of precast concrete construction, the weaknesses required to improve in the construction industry are also discussed.

Chapter 6 concludes the main research findings and presented the contributions from this research. Furthermore, it discusses the advantages of new readiness model called PCCRM model and limitations of research. Finally, it ended with suggestions for future study.

CHAPTER 2
LITERATURE REVIEW

This chapter can be mainly divided into two parts. The first part discusses about overview of precast concrete, essential characteristics and market experience of precast concrete in various countries. In the second part, it presents the definition of readiness and review of readiness models, tools and frameworks from various industries. Thus, this chapter gives information on precast concrete construction around the world and readiness models that are available in the literature.

2.1 Overview of Precast Concrete

In this section, the definition and categories of precast concrete are discussed and advantages, hindrances and factors affecting the adoption of precast concrete construction are reviewed intensively through literature review. Then, the advantages, hindrances and the factors are documented to use in development of a new readiness model for the adoption of precast concrete construction.

2.1.1 Definition

Using the precast concrete method is a widely accepted alternative method to the conventional cast-in-situ construction method. Precast concrete is one of the construction materials that are produced at off-site, usually in a controlled environment by using reusable molds or forms and then carried to the construction site for assembly (Jaillon & Poon, 2009; Richard, 2005; Teng, Mao, Liu, & Wang, 2017). Basically, there are four processes in precast concrete construction: design, production, transportation and assembly (Steinhardt & Manley, 2016). Precast concrete is one that falls under the broad umbrella of Modern Method of Construction (MMC), Offsite Construction (OSC), Offsite Manufacturing (OSM), Offsite Production (OSP), Pre-assembly, Industrialized Building Systems (IBS) and Prefabrication which are used to mention in the construction industry. However, A. M. Kamar, Hamid, and Azman (2011) said that regardless of the terms, all of them referred to manufacturing the components under the controlled environment for the construction building rather than cast-in-situ.

2.1.2 Categories of Precast Concrete

Glass (2000) mentioned that according to a survey of housebuilders and housing associations in the UK, generally precast concretes were divided into three broad categories that were commonly used within UK house buildings. Those are

- Components
- Panels (2D construction)
- Volumetric (3D construction)

Components

Usually, components are linear elements and joints are filled with concrete at the site. Using precast concrete in components is the most popular one. Walls, beams, floors, columns, lintels, and stairs are typical precast components used in housing construction.

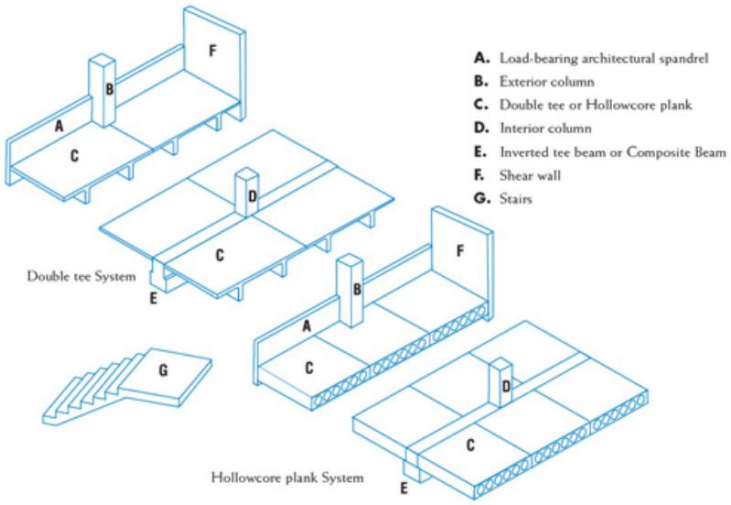

Figure 2.1:Precast Concrete Components

(Source: PCI Mid Atlantic)

Panels (2D construction)

Using precast wall panels is becoming popular in building construction because of their advantages such as faster construction, simple construction process and good quality. Loadbearing wall elements can be applied in two arrangements: cross-wall and spine wall arrangements. The most likely option for low-rise housing is cross-wall construction with party walls between rooms performing as the main structural elements. In the UK, single-story height with 90-300mm thick concrete

wall panels for external wall and 70-100mm thick concrete wall panels for internal wall are typically used in single or two-story housings.

Figure 2.2: Precast Concrete Panels

Volumetric (3D construction)

The term ‘volumetric construction’ means constructing the whole room modules (pods) or joining individual cast panels together in control environment or the factory to make rooms. Nowadays, it is getting more prevalent in housings and other constructions that use multi-cell structure. By using the benefits of the control environment factory, volumetric construction creates entire rooms and it is used mostly in service-intensive building components such as ‘pot’ kitchens and bathrooms for the market where is required for rapid assembly on site.

Figure 2.3: Precast Concrete Volumetric Construction

2.1.3 Advantages of Using Precast Concrete

The application of precast concrete technology can offer several advantages for all project participants rather than using traditional construction methods (cast-in-situ).

Using precast concrete can provide less construction time and early building enclosure as manufacturing and assembling processes are not affected by uncontrolled weather and labors' productivity (Polat, 2010). As stated in the case study of Gunawan (2013), among three different construction projects, it was found out that total working days for precast building required only 60 to 65 days instead of 154 days. Moreover, according to Rahimian, Goulding, Akintoye, and Kolo (2017), the project delivery time could be faster 30-50% than the traditional method because of conducting parallel activities.

Glass (2000) asserted that fire resistance, thermal performance, and sound insulation were the advantages that were relevant to house building. 150 mm thick concrete wall can resist the fire over 90 minutes that is more than the requirement for most housing (Glass, 2000). As reported by (Glass, 2000), normal density concrete could get the thermal performance by absorbing and storing the heat in the building structure. As recent tests for comparing the energy efficiency of concrete and timber house, the concrete house maintains the temperature around 3 to 4 `C during the summer season (Thomas, 1999). Concrete panels offer an intrinsically solid house that has high acoustic performance and as the mass law of sound reduction, a solid element will improve the sound reduction approximately index by 4dB (Glass, 2000).

By using precast concrete method, overall cost saving can be achieved directly and indirectly from the areas such as: requiring minimum labor usage, time-saving, cost certainty, reducing maintenance cost, preliminaries and site overheads cost, requiring less construction time and less building materials wastages (Chan & Hu, 2002). Pan and Sidwell (2011) conducted the cost comparison in detail among 20 residential buildings used four different types of construction methods and then they found that using the precast cross wall system was cheaper than other methods.

Another advantage of using precast concrete is getting high-quality control and assurance. Jaillon and Poon (2008) mentioned that while the quality of the building that used traditional methods highly relied on the construction workers' workmanship and supervision, the quality of the precast building was easier to control since precast concrete components were manufactured in a factory environment. In addition, using precast concrete methods can reduce the defects on-site and improve the durability

and quality of precast concrete components since those are inspected before transporting to the site. Moreover, producing precast concrete components by high-tech machinery with computer-aided technology leads to premium quality and high durability products (Hamill, Bertolini, Biebighauser, Bechara, & Wilden, 2006; Neville, 2006).

One of the popular advantages of using precast technology is minimizing the wastes causing at the construction site (Ting et al., 2019). Earlier researchers have shown that 70% of water, 20% of energy consumption and 87% of timber formwork usage at the site can be reduced and overall 30% of total waste is reduced when compared with cast-in-situ building project (Jaillon & Poon, 2008).

By choosing prefabrication, builders can overcome the labor shortage problem as it is not required many labor usage on-site since the production works are carried out in the factory (Cao, Li, Zhu, & Zhang, 2015; Jiang, Mao, Hou, Wu, & Tan, 2018). According to Jaillon and Poon (2008), labor requirements can be reduced from 16% to 30% averagely in some project.

Lam, Chan, Wong, and Wong (2007) revealed that the adoption of precast concrete system provided enhancing health and safety matters because many activities were not necessary to conduct on-site and Jaillon and Poon (2008) found that accident rates were lower than 63% as their case study. Table 2.1 listed the advantages of using precast concrete construction from the literature review.

2.1.4 Hindrances of Precast Concrete

In order to uptake precast concrete technology, it is important to know the possible hindrances of precast concrete in construction. There are different hindrances in different countries where precast concrete is adopted, and many researchers have explored and investigated them. For instance, Jiang et al. (2018) have presented that lack of government policy and regulation was one of the major hindrances to uptake precast concrete technology successfully. And it made developers, investors and customers to be reluctant to use precast concrete. Moreover, according to the government of Hong Kong (2002), government promotion and incentives were required to pull the private sector in the adopt the prefabrication (Khuan, 2011).

Table 2.1: Advantages of Using Precast Concrete Construction

Advantages	Author
1. Less construction time	Polat (2010), Gunawan (2013), Rahimian et al. (2017)
2. Fire resistance, thermal performance & sound insulation	Glass (2000), Thomas (1999)
3. Overall cost saving	Arif et al. (2012), Chan and Hu (2002), Tam, Fung, Sing, and Ogunlana (2015), Pan and Sidwell (2011)
4. High-quality control and assurance	Jaillon and Poon (2008), Hamill et al. (2006),
5. Minimizing the wastes	Ting et al. (2019), Baldwin, Poon, Shen, Austin, and Wong (2009), Baldwin et al. (2009)
6. Less labor requirement	Cao et al. (2015),Jiang et al. (2018),Jaillon and Poon (2008)
7. Enhancing health and safety	Lam et al. (2007), Jaillon and Poon (2008)

Lack of appropriate design codes, standards and guidelines were also barriers associated with the adoption of the precast concrete system. Arditi, Ergin, and Günhan (2000) presented the existence of nationwide guidelines and standards are very important for the overall success of the precast concrete system.

Another hindrance is the lack of awareness and negative perception of the public and stakeholders toward precast concrete. Arditi et al. (2000) revealed that unawareness of potential benefits of prefabrication was the main factor that blocked the tremendous use of that system in the building construction industry of the U.S. And lack of experts and professionals in precast concrete technology led to a hindrance to implement the precast concrete projects. Luo, Mao, Shen, and Li (2015) said that poor management, design, production and poor erection made errors and defects in design, conflicts among the parties, project delay and imperfect operation.

In the past, there were some limitations for the use of precast concrete components under high seismic area because of poor earthquake performance. In 1992, 1995 and 1999 earthquake, the performance of precast concrete buildings in Turkey resulted in great deformation and severe failures because of distress in the joint and connection. However, nowadays, precast concrete components system can be designed and constructed to resist the high earthquake forces because of intensive research and testing of precast components joints (Yee & Eng, 2001). Moreover, VanGeem (2006) said that precast concrete framing system with proper design could resist the major earthquake and it have proven that there was adequate capacity to withstand these major earthquake. According to Crisafulli, Restrepo, and Park (2002), among precast concrete system, precast concrete panel system can be applied advantageously to obtain performance of earthquake resistance in low rise building. In the 1998 earthquake in Armenia, among the four different structural building types, only the panelized precast concrete structure buildings were the one which survived (Arditi et al., 2000).

Another hindrance associated with the uptake of a precast concrete system is the lack of R&D and technology center. As one of the case studies in China, contractors are hesitant to adopt a precast concrete system for the construction buildings because there is no laboratory to test and prove the quality of the products. In addition, no investment in research and development will be a barrier for the stakeholders to make the decision for using the precast system because of limited information (Zhang & Skitmore, 2012).

The next hindrance is reworked design and change issues. Khuan (2011) expressed local designers had implied an unwillingness to do re-design for the building that was designed based on the traditional approach to change to prefabrication as their effort has been done under design fee that they got. Moreover, when manufacturer has produced the components as agreement, changes will not be allowed without additional cost (Blismas & Wakefield, 2009). And lack of economies of scales also will prohibit the adoption of the precast concrete system, especially for the manufacturers. It will be unfeasible to establish the precast factory if there is no order

for mass production or if every ordered component is different design and shape that need various casting mold and beds (Zhang, Skitmore, & Peng, 2014).

Blismas and Wakefield (2009) reported that transportation issue was one of the major hindrances needed to be considered for the uptake of precast concrete technology as transportation of huge and heavy components were restricted according to the size of the item, widths of the road and limitation of bridge capacities, transportation rule and regulation. Likewise, Polat (2010) revealed that the permitted weights and sizes of carrying amounts were regulated by highway agencies according to the payload of bridges, roads and size of tunnels, underpasses and travel time for over-dimension vehicles. Another hindrance in using the precast concrete system for the construction site located in the urban area is the lack of on-site access and limited space. As consequences from that hindrance, stakeholders will cancel to choose the precast concrete system for their projects since space to keep the components at the construction project is required temporarily before erection (Ting et al., 2019).

According to the characteristic of the precast concrete system, it makes long lead-in time for the clients, designers and contractors since planning, design and production need to be done before transportation and erection are started. As a consequence, stakeholders feel that using precast concrete could delay the commencement of the construction project on-site because of long lead-in time. Monotone type of precast concrete shape is also one of the disadvantages of precast concrete because it cannot offer diversity and customization of consumers (Luo et al., 2015).

One of the drawbacks of precast concrete is high initial cost due to requiring the cost of manufacturing at the factory, a set of fabrication mold, equipment and machines (Jaillon & Poon, 2008). Jiang et al. (2018) revealed that initial cost of precast concrete construction method was 20% higher than the normal conventional method. And monopoly dominance issue also should be considered in the beginning period of adopting precast concrete technology when there are a few suppliers for precast components (Mohamad, Zawawi, & Nekooie, 2009).

Lastly, Arif et al. (2012) argued that poor coordination and collaboration were the potential hindrances of uptake precast concrete technology. Using precast concrete construction method is not the same as the normal conventional cast-in-situ method

because there is an additional process such as manufacturing at the factory, transporting to the site, erection and assembly of precast concrete components. Thus, it requires many practitioners and interfaces to deliver the project successfully with good problem-solving skills, effective communication and collaboration, teamwork and analytical skill (Luo et al., 2015). All of those possible hindrances discussed above are important to consider in the development of a new readiness model for the adoption of precast concrete construction. Hindrances of the adoption of precast concrete from the literature review are shown in Table 2.2.

Table 2.2: Hindrances of the Adoption of Precast Concrete

Hindrances	Author
1. Lack of government policy and regulation	Jiang et al. (2018), Rahimian et al. (2017), Ting et al. (2019)
2. Lack of government promotion and incentives	Khuan (2011)
3. Lack of appropriate design codes, standards and guidelines	Arditi et al. (2000)
4. Lack of awareness and negative perception	Arditi et al. (2000)
5. Lack of experts and professionals	Luo et al. (2015)
6. Poor performance under high seismic load	Polat (2008), Sezen and Whittaker (2006)
7. Lack of R&D and technology center	Zhang and Skitmore (2012)
8. Rework design and change issue	Khuan (2011), Blismas and Wakefield (2009)
9. Lack of economies of scales	Zhang et al. (2014)
10. Transportation issue	Blismas and Wakefield (2009), Polat (2010)

11. Lack of on-site access and limited space	Ting et al. (2019)
12. Long lead-in time	Luo et al. (2015)
13. Monotone type	Luo et al. (2015)
14. High initial cost	Jiang et al. (2018), Jaillon and Poon (2008)
15. Monopoly dominance issue	Mohamad et al. (2009)
16. Poor coordination and collaboration	Arif et al. (2012), Luo et al. (2015)

2.1.5 Critical Success Factors of Precast Concrete Construction

The critical success factor is involved in a vital role for achieving a successful project and the practitioners have to know before the project commences or during the implementing period. The critical success factor is one that makes the project success or failure. Tammy et al. (2016) defined that critical success factors were contributing factors that make secure the project to complete successfully.

According to the literature review, researchers have identified critical success factors that affect to execution of Industrialized Building System (IBS) projects. These include:

- **Effective Communication**: According to Musa et al. (2016), effective communication is an important factor to make sure no miscommunication among project members (contractor, consultant, manufacturer, and client). Moreover, Blismas and Wakefield (2009) revealed that in order to coordinate along the process and to deal with time schedule starting from project initiation state to completion of the project, effective communication through the members and the supply chain was required.
- **Good working collaboration**: Collaboration is a process in which two or more people work together to achieve a mutual interest or goal. Lack of collaboration leads to arising problems such as delaying the project, cost overrun and wasting resources. Thus, it is vital in the construction project as many parties need to work together from the beginning of the project to the

project completion. The good working collaboration will resolve the problem that happened due to a lack of communication and lack of sharing information in both manufacturing factories and construction sites (Lu & Liska, 2008; Y.-h. Pan, 2007).

- **Team member involves during the design stage**: In order to avoid problems in the construction period, all of the team members of the project should involve in the design stage. In addition, misunderstanding and dispute can be prevented by involving during the design stage of the project (K. Kamar, Hamid, & Alshawi, 2010; Musa et al., 2016).
- **Extensive planning and scheduling**: Extensive planning and scheduling are crucial to achieve the successful implementation of precast concrete construction. Well planning and scheduling in the early-stage lead to better coordination and better performance of the project (K. Kamar et al., 2010).
- **Training and education**: K. Kamar, Alshawi, and Hamid (2009b) stressed that training and education were required in the application of precast concrete construction because a greater level of precision, technique and skill labors were required for assembling and installation of the precast components.
- **Experience and technically capable workforce**: Warszawski (2003) stressed that successful implementation of precast concrete construction required experience and technically capable workforce for design, managing and controlling activities with regard to coordination, production, transportation and logistics of components. Moreover, According to Mohamad et al. (2009), the involvement of high experience persons in the construction organization makes the organization ready for the adoption of precast concrete construction technically and mentally.
- **Top-down Commitment**: Top-down commitment means the commitment of the top management to general workers need to work as a team. The commitment of top management of the organization is vital to achieving a successful precast concrete construction implementation. Management's commitment, adequate support, resources, and top-down approach are required in the implementation of precast concrete construction (K. Kamar et al., 2010; Musa et al., 2016).

- **Management of supply chain and logistics**: Ismail, Yusuwan, and Baharuddin (2012) defined that supply chain management was as a product or service starting from supplier process to end-user or customer. And supply chain management involves all stages of precast concrete construction implementation including the production of precast components at manufacturing factory, transportation to the project, assembling and finishing. In addition, precast concrete construction requires good coordination and supply chain management because the current construction industry supply chain is fragmented as a result of poor communication and lack of commitment (K. Kamar et al., 2009b).
- **Procurement Strategy**: Application of information technology for materials management processes is very effective and productive. The technology improves project delivery processes such as tendering, cost comparison, planning, monitoring, logistics and so on by creating the integrated collaborative design, accurate data and effective handling the documents of the project (K. Kamar et al., 2010).
- **Design Standardization**: It is required to emphasize on design standardization for being more effective usage as repetition concept. The design and product are kept a document systematically to make sure that everything is same manner for manufacturing and installation (K. Kamar et al., 2009b).
- **Information and Communication Technology (ICT)**: According to K. Kamar et al. (2010), Information and communication technology (ICT) is an effective supporting tool to improve project delivery processes (tendering, cost controlling, planning and so on) in the implementation of precast construction and ICT helps to solve the communication problems of the construction project.
- **Coordination of design, manufacturing, and construction**: Warszawski (2003) mentioned that coordination in design, manufacturing, installation and other processes were crucial in the implementation of precast concrete construction because it needed more accurate process planning and control to

decrease defects and errors due to precise design, production, and assembling of precast concrete components.

- **Machinery and Equipment**: Special machinery and equipment are essential for manufacturing, transportation, and assembling of precast concrete components and it will make a higher rate of production output and work progress compared to the normal traditional methods. On the other hand, investment for buying new machinery, equipment, mold and skilled workforce wages make the high initial cost of precast concrete construction (Musa et al., 2016).
- **Continuous improvement and learning**: According to K. Kamar et al. (2010), successful implementation of precast concrete construction relies on the capability of the organization to improve the learning curve from one project to another project. Therefore, the behavior of continuous improvement and learning can make the company understand the process.
- **Skilled labor for site installation:** Although the application of precast concrete construction can reduce the number of skill labor usage, it still needs skilled labor for managing, handling and erecting the components of the precast concrete at the site. Therefore, the workers still require to be trained in order to make sure their skill is whether adequate for implementation of precast concrete (K. Kamar et al., 2010; Thanoon, Peng, Kadir, Jaafar, & Salit, 2003).
- **Knowledge and Awareness:** Mohamad et al. (2009) revealed that unfamiliar and lack of knowledge and awareness of the precast concrete advantages and concepts were some of the major factors that made players feel difficult in the adoption of precast concrete construction. Hence, client and decision-makers become less interest in using precast concrete construction.
- **Proper Guideline:** The proper guideline involves an important role to be smooth delivery of the precast concrete construction process. Mohammad, Shukor, Mahbub, and Halil (2014) specified that different guideline and understandings of different organizations in a construction project could make problems and disputes during the implementation of precast concrete construction.

- **Safety and Health:** Safety and health are very important issues not only for the precast concrete construction but also for every saturation. Precast concrete construction can create a better safety and healthy working environment by working in the factory that is under control environment and by reducing the activities that are needed to work in the uncontrol environment (Musa et al., 2016).
- **Risk management strategy:** Bendi (2017) defined that conducting risk management was a crucial factor in precast concrete practices because it provided contingency measures to deal with unexpected cases such as delays, accidences and disruption at every stage of the implementation of precast concrete construction.

Table 2.3: Summary of Critical Success Factor

Critical Success Factor	**Author**
1. Effective Communication	Musa et al. (2016), Blismas and Wakefield (2009)
2. Good Working Collaboration	Lu and Liska (2008),Y.-h. Pan (2007)
3. Team Member Involvement during the design stage	K. Kamar et al. (2010), Musa et al. (2016)
4. Extensive Planning and Scheduling	K. Kamar et al. (2010)
5. Training and Education	K. Kamar et al. (2009b)
6. Experience and Technical Capable Workforce	Warszawski (2003), Mohamad et al. (2009)
7. Top Down Commitment	K. Kamar et al. (2010), Musa et al. (2016)
8. Management of Supply Chain and Logistics	Ismail et al. (2012), K. Kamar et al. (2009b)
9. Procurement Strategy	K. Kamar et al. (2010)

10. Design Standardization	K. Kamar et al. (2009b)
11. Information and Communication Technology (ICT)	K. Kamar et al. (2010)
12. Coordination of Design, Manufacturing and Construction	Warszawski (2003)
13. Machinery and Equipment	Musa et al. (2016)
14. Continuous improvement and learning	K. Kamar et al. (2010)
15. Skilled labor for site installation	Thanoon et al. (2003), K. Kamar et al. (2010)
16. Knowledge and Awareness	Mohamad et al. (2009)
17. Proper Guideline	Mohammad et al. (2014)
18. Safety and Health	Musa et al. (2016)
19. Risk management strategy	Bendi (2017)
20. Government policies	Mohammad et al. (2014)
21. Business approach	Bendi (2017)

- **Government policies:** Government policies are one of the important factors in the adoption and promoting of precast concrete construction. In Malaysia, the government established a policy for its projects to use not less than 70 percent of IBS components. The objective of the policies is to create momentum and demand for IBS components (Mohammad et al., 2014).
- **Business approach:** Bendi (2017) revealed that management required to set up the clear business plan and develop a strategic plan for offsite construction including an effective cost combination and production knowledge.

The list of critical success factors affecting the adoption of precast concrete from the existing literature review is presented in Table 2.3.

2.2 Essential Characteristics of Precast Concrete

Thanoon et al. (2003) revealed some characteristics that were essential to be a successful implementation of an industrialized building system (IBS). Since precast concrete is the one under the umbrella of IBS, its essential characteristics are similar. Those characteristics are briefly discussed below.

2.2.1 Closed System

According to (Yunus, 2012), a closed system means precast components used in the project are produced by individual manufacturer. And builders are not allowed to use and install together with other precast components that produced by other manufacturers in the project. A closed system can be divided into two categories which are manufacturing depending on the client's design and precaster's design. The first one is designed to fulfill the client's dimensional requirements for miscellaneous functions of the building as well as detail design for the architect. In that case, the client's requirements are vital and precaster are compelled to manufacture the components of a building that the client needs. And the second category: manufacturing depend on precaster's design is designing and manufacturing a standardized class of building or a set of components. Generally, low-cost housing, gas station, school and car parking included in the second category. Nonetheless, these types of building can be feasible in term of economic when the following conditions are discovered (Thanoon et al., 2003).

(a) The project size is adequate to distribute the cost of precast concrete components' design and production.

(b) The architectural design of the project is used repetitive components and standardization. In that case, the requirement of many standardized components can be solved by using a modernistic prefabrication system that can operate the automating design and production process.

(c) There is a project with a sufficient amount of typical building type such as low-cost housing that can create mass production.

(d) There is a comprehensive marketing strategy by precaster which makes stakeholders understand and get awareness about the potential advantages of the precast concrete system, especially regarding economics aspect.

2.2.2 Open System

According to Thanoon et al. (2003), the open system permitted the precaster to manufacture a limited number of components with a planned and estimated amount of components and to maintain architectural aesthetic design concurrently. Therefore, the open system provides better flexibility for design and coordination among stakeholders because the opened system allows using components from different manufacturers. Although there are several advantages to an open system, it still has one major setback. For instance, joint and connection problems are found when components from the different systems are installed together. However, this problem can be solved by using similar connection design in order to attain better structural performance.

2.2.3 Modular Coordination

Modular Coordination is a concept for coordinating of measuring the size and space in which buildings and components are measured and arranged in terms of basic units or modules. So, all the components can be assembled without needing modification although the components are produced by other suppliers.

According to Warszawski (2003), modular coordination was developed for two objectives. The first objective is to reduce the variety of building components' sizes and to attain dimensional compatibility in building dimensions, span or spaces and components' sizes. In order to achieve the first objective, building components' dimensions are limited to standardized sizes and measurement unit.

And the second objective is to be easy for adaptation of precast concrete components to any layout and for their interchangeable with others within the building. To accomplish the second objective, the positions of each component in the building are determined by taking reference to a common modular grid, rather than taking reference to other components.

The standard of the modular coordination for building components specifies the basic unit or module defined as "1M" that is equivalent to 100 mm, and then the building and components are set in their designed position according to the basic unit module. The modular coordination is applied in the design, manufacturing, construction of the building, assembly of the components and installation.

It helps construction stakeholders to have good communication among them by using common dimensional language. Therefore, the utilization of modular coordination is to minimize errors, correction at the site and material wastages. Furthermore, adoption of modular coordination offers better durability, security, habitability and less construction time. However, the major barriers of the application of this standardization are lack of knowledge among construction stakeholders, requiring proper planning and precision dimensioning (Yunus, 2012).

2.2.4 Standardization and Tolerances

All components require to be standardized for manufacturing to accomplish the requirement of modular coordination. Developing the standardization of space and components are required for tolerances at various construction stages such as erection tolerances, setting out tolerances, manufactured tolerances and etc. That is to ensure total combination of tolerances attained from statistical calculation is within the allowable limits of tolerance. The application of standardization and tolerances will help manufacturers to get standardized output by using production resources in the most efficient manner (Thanoon et al., 2003).

2.2.5 Mass Production

Since the investment amount for precast concrete production factory, equipment, resources and facilities are very costly, it can be feasible only for large amount of production volume because such volume makes the fixed investment cost distribute over a large number of production units (Thanoon et al., 2003).

2.2.6 Specialization

Mass production output and standardization of precast components make a high level of labor specialization within the production process. The process can be subdivided into many small assignments. In that working situation, workers conduct their assignments repetitiously with a high productivity rate (Warszawski, 2003).

2.2.7 Good Organization

Good organization means an organization that has abilities and capabilities to conduct high level of planning, well organizing the team, good coordination and well controlling for manufacturing and distribution of the precast products. Experience and

good organization are required to obtain high productivity rate, specialization in work and centralized manufacturing (Thanoon et al., 2003).

2.2.8 Integration

Precast construction is different from the traditional construction method because it involves additional parties and activities. Thus, a high level of coordination is needed among various related parties and activities in order to obtain an optimal result. This can be implemented by adopting an integrated system in which all of these functions are conducted under a unified authority (Warszawski, 2003).

2.2.9 Production Facility

The initial investment cost to fulfill production facility for the permanent precast concrete factory is extremely costly and all the resources for the factory require to be ready before production is started. Such a huge investment cost can only be breakeven when the production units meet the concepts of economics scale. However, setting up a temporary production yard or factory at the site can reduce transportation and investment costs.

2.2.10 Transportation

Thanoon et al. (2003) revealed that although the casting of the large precast concrete panel could minimize labor costs up to 30 percent, on the other hand, that minimizing cost was partially offset by transportation cost. Blismas and Wakefield (2009) reported that transportation issue was needed to be considered for the uptake of precast concrete technology as transportation of huge and heavy components were restricted according to the size of the item, width of the road and limitation of bridge capacities, transportation rule and regulation.

2.2.11 Equipment at Site

Since hoisting equipment and cranes are required to erect and assemble precast concrete panels into their position, it is important to consider the additional cost of hoisting crane and available space at the site for the crane when prefabrication system is adopted (Thanoon et al., 2003).

2.3 Market Experience of Precast Concrete in Various Countries

Many people of the construction industry in the world are considering precast concrete construction as one of efficient alternative construction methods because of offering significant advantages such as the easier and quicker construction for building structure, achieving lower project cost, better quality, better durability, less building material wastage and so on (Polat, 2008). In recent decades, the use of precast concrete construction has risen dramatically in many countries. While developed countries such as the UK, the US, Japan and others have widely accepted it, middle income developing countries are trying to adopt precast concrete technology in order to attain competitive advantages in the construction industry (Arif et al., 2012). Below is some review of the experiences and implementation of precast concrete construction in various nations.

2.3.1 United Kingdom

In the United Kingdom, the acute need for housing demand, delay in completion and cost overruns are one of the challenges for the construction industry, together with skilled labor shortage and skill gaps (Pan & Sidwell, 2011). The UK Interdepartmental Committee on Housing construction commenced to promote new construction methods and materials to upgrade productivity, speed of construction and construction economy (Waskett, 2001). Precast concrete construction was supremely considered as a feasible approach to deliver the high-quality and innovative solutions with cutting-edge design (Rahman, 2013). In the UK, precast construction is grouped under the big umbrella of 'Modern Methods of Construction' (MCC) that broadly consists of 'offsite' methods (Steinhardt & Manley, 2016).

Glass (2000) mentioned that the application of precast concrete construction became more noticeable in the mid-1900s after many houses were destroyed at the time of the Second World War. In 1960, over 165,000 precast concrete houses which were included small single houses and large high-rise buildings had been constructed.

According to Glass (2000), in 1999, precast concrete represented around 25% of cementation products market in the UK. This contained a verity of products used in the construction industry, for instance, suspended floors, architectural cladding, paving, cast stone, structural frame, blocks, structural elements and bridges. Among

these precast concrete products, suspended floors were the most selling product sold in terms of tons per year and 45% of precast concrete are used in housing projects: around 1.5 million tons of precast concrete usage for new houses every year.

The huge demand for housing was a key driving force for the adoption of precast concrete construction in the UK together with the comprehensive government promotion (Goodier & Gibb, 2007). Many government programs such as the formation of Constructing Excellence of the Deputy Prime Minister Office, housing agenda of UK government and the Housing Forum supported the adoption of precast concrete construction (A. M. Kamar et al., 2011; Pan & Sidwell, 2011).

Many researchers have revealed that the offsite method was a potential solution for the problem of the UK construction industry (Goodier & Gibb, 2007). In the UK, the housing forum and Build offsite (UK based business organization) have intensively developed an offsite method to handle the huge demand for affordable housing and to get better achievements in the construction industry (Arif et al., 2012). Nadim and Goulding (2010) suggested that supporting adequate training and education was one of the ways to make people accept, be aware, appreciate and adopt new methods and technologies.

The problems of the UK construction industry in the past were similar to Myanmar's current construction problems. Those were the requirement to fulfill huge housing demand, time and cost overrun and skill labors shortage. In the end, the UK construction solved those problems by the adoption of the Modern Method of Construction (MMC).

2.3.2 United State of America

Prefabricated construction was used in the United State of America since the beginning of the nineteenth century. According to Glass (2000), 30% of all houses in the USA were prefabricated and even though most of the houses are low-rise housing, precast concrete system was used progressively, especially in the areas where are exposed to environmental disasters such as cyclone and tornados. Polat (2010) revealed that the use of precast concrete system took generally 1.2% share of the U.S overall building construction market. As reported by the PCA (Portland Cement

Association), precast concrete wall panel systems were utilized for low-rise housings in many states of USA.

Lu and Liska (2008) presented that the housing construction industry of USA played an important role in the major use of prefabricated techniques. The present housing market of USA is pushing home builders to make integration and investment in new technologies such as prefabrication. Alongside this, the rising interest of sustainable construction pushed the application of prefabrication in the construction industry (Bendi, 2017). Li, Al-Hussein, Lei, and Ajweh (2013) said that modular construction was extensively used as one of the efficient construction methods, especially for a residential housing projects in Northern states of America. Some companies have produced customized products such as large and energy-efficient residential buildings. In the U.S, prefabrication method was widely used in residential buildings, educational, healthcare and office building construction sectors when compared with application of prefabrication in commercial and infrastructure project (Azman, Ahamad, & Hussin, 2012).

According to (Lu & Liska, 2008), there were some major barriers while adopting the prefabrication method in USA. Those were restraints about transportation, limitation of design options and lack of services to conduct revised designs during onsite implementation. Moreover, other researchers pointed out other factors such as lack of awareness on the advantages, misconceptions about modular construction and reluctance to adopt new technology are barriers of the adoption of precast concrete techniques in the U.S construction industry (Bendi, 2017; Eastman, Sacks, & Lee, 2003; Lu & Liska, 2008). After review about precast concrete construction in the U.S, it points out to consider some major drawbacks when the precast concrete construction is adopted.

2.3.3 China

Since the 1980s, precast concrete technology was started to fulfill the housing market supply and, in that period, there were many significant explorations of building industrialization in China. For instance, in 1987, the government issued standard for Modular Coordination of Building (GBJ2-1986) that mainly used for the unity and

coordination of the modules. In 2006, the ministry of construction issued the 'National Housing Industrialization Base Implementation Outline'. (Wang He, 2017).

Zhang and Skitmore (2012) said that China was experiencing a change from a conventional labor-intensive method to modern technology in its housing construction industry in the form of housing industrialization (commonly known as prefabrication housing). Moreover, according to Y.-h. Pan (2007), there were great opportunities for manufactured housing in China and housing industrialization has been popular more and more as one of the major alternative construction methods. Jaillon and Poon (2008) revealed that the application of prefabrication offered significant benefits of social, environmental and economic when compared with normal traditional construction methods in China.

Prefabricated buildings were firstly adopted along with public housing projects in Hong Kong. In the mid-1980s, the Hong Kong Housing Authority (HKHA) introduced a combination of prefabrication and standard modular design for the housing projects. The HKHA has pushed to use precast concrete elements and other sustainable building construction methods and technologies in all of the government housing projects. In 2005, HKHA planned to use precast components in a pilot project about 65% including structural wall and precast kitchen. However, traditional construction methods are still used in Hong Kong private construction sector (Jaillon & Poon, 2008). In China, the government was one of the key drivers to adopt prefabrication techniques in the construction industry.

2.3.4 Japan

In Japan, the industrialization of housing projects was started in the 1960s. Starting from that period of time, the market share of precast concrete usage has been changing significantly (Nagahama, 2000). From 1999 to March 2000, prefabricated housing construction market share in Japan indicated 20 percent of the whole housing construction market of Japan. Among the prefabricated housing market, the steel framing system took 73 percent share, the usage of wooden frame system's market

share was 18 percent while the application of precast concrete system scored only 9 percent of the prefabricated housing market.

Based on that score, later, the application of wood-framed housing increased 2 percent and the usage of steel housing rose 3 percent, while the application of precast concrete housing became highest with 12 percent. Since 2000, Japan began to pay more attention to the construction for being long life residence and the Hundred Year Housing Scheme was proposed (Wang He, 2017). The market experience of precast construction in Japan showed that the application of precast concrete for housing projects increased more than other prefabricated systems.

2.3.5 Malaysia

In Malaysia, the Industrialised Building System (IBS) similar to prefabricated or off-site construction was introduced in the 1960s (Bendi, 2017). According to the Construction Industry Development Board (CIDB-Malaysia), IBS is defined as "a construction technique in which components are manufactured in a controlled environment (on or off-site), transported, positioned and assembled into a structure with minimal additional site work". Mydin, Sani, and Taib (2014) stated that IBS could be classified into five systems: 1) Precast concrete system, 2) Steel formwork system, 3) Steel framing system, 4) Prefabricated timber framing system and 5) Bock work system.

Malaysia's government introduced and promoted to mitigate the intensive use of foreign labors in the construction and to get better impression of the construction industry, together with its advantages (K. Kamar, Alshawi, Hamid, et al., 2009). Moreover, IBS was one of potential alternative construction methods to cope with acute housing demand and sustainable development of the Malaysia construction industry. For instance, the "7th Malaysia Plan (1996-2000)" outlined a housing plan to build 800,000 houses approximately for public and private sectors. In addition, using normal conventional construction methods could not perform to meet the demand for housing because of the slow speed of project delivery and higher cost, along with the threatening of getting unskilled labor and higher building material wastages (Bendi, 2017).

On the other hand, K. Kamar, Alshawi, Hamid, et al. (2009) pointed out that the adoption rate of IBS in Malaysia construction sector had been low, with only 10-15% of the overall market of construction during 2003-2006. There were some IBS projects that obtain unsuccessful results in time delay and cost overrun due to poor project management. As a consequence, the stakeholders from the construction industry reluctance to adopt IBS technology.

Later, the Malaysia government embraced and promoted the application of IBS by setting up intensive promotion and strict instruction to use IBS. In addition, CIDB developed a roadmap named the "IBS Roadmap 2003-2010". Those actions gave a direction for IBS implementation, promotion and incentive activities. Malaysia is one of the countries earnestly introducing the application of IBS to cope with acute housing demand and mitigate the reliability of foreign labor in the construction industry.

2.3.6 Singapore

According to the Building and Construction Authority (BCA) of Singapore, the application of precast components in Singapore was very limited to civil engineering works in the 1970s. Then, in the early 1980s, the precast concrete components for the building took off when the "Housing and Development Board (HDB)" introduced massive industrialized housing for public housing program. Moreover, Poh and Chen (1998) mentioned that the off-site construction method was developed in Singapore along with using precast reinforced concrete technology in the multi-story building construction projects.

The Housing Development Board (HDB) of Singapore used a strategy to overcome the skilled labor shortage problem, to attain better quality and faster construction speed in construction projects. That strategy was to promote fully precast concrete construction method and semi-precast concrete construction method in construction industry. Moreover, HDB made a milestone achievement for the application of precast concrete that is establishing the Prefabrication Technology Centre (PTC) in 1994.

According to Kong (2009), the application of precast concrete technology was become popularity in the Singapore construction industry because of its advantages.

In recent years, HDB has announced major innovation of its own research center about prefabricated components such as precast concrete chute, precast volumetric house, precast concrete column, precast exterior walls and precast concrete parapet and so on. The key to the successful utilization of precast concrete methods in Singapore was the standardization of precast components.

2.3.7 Thailand

Thailand is one of the countries which is earnestly using precast concrete construction method in its construction industry. Around the year of 1992, the precast concrete system was begun in Thailand. Many new adopter companies in Thailand took the precast technology from another countries in order to apply in the development of their housing projects (Chaimahawan, Hansapinyo, & Phuriwarangkhakul, 2018). According to Ngoenchuklin (2014), last twenty years ago, construction labor wages were very cheaper than it in today. At that moment, the typical construction method for building projects in Thailand was “Post and Beam” which was relied on the use of intensive labors which could be available with cheap wages. Then, starting from recent years, the construction labor wages in Thailand has been increasing. According to Thailand Ministry of Labor, from 2011 to 2013, the minimum labor wage in Thailand increased double from 150 bath to 300 bath. Therefore, many housing developers and construction contractors tried to adopt the new construction method such as precast concrete method in order to reduce the labor cost.

In addition, after the Asian financial crisis in 1997, Thailand construction business was slowly developing. Starting from 2000, Thailand construction has been significantly grown in several sectors such as commercial buildings, residential buildings and health care centers. The major factor that drive the construction business to grow were the government immigration policies and foreign investments. In order to grab the opportunity of the growing market, Thai developer required to develop and construct more projects fastly by using some alternative construction method. Therefore, some developers chose precast concrete construction method. During the period of 2003 and 2005, affordable housing and townhouses became the target to apply the precast concrete construction. Among Thai developer companies, Pruksa Co.ltd was the first company which apply the precast concrete construction in

housing successfully. Then, many developer and contractor companies also started to use precast concrete in their projects. Although the cost of the houses builded by precast concrete method is a little expensive than typical construction method, roughly 3% for 100 square meter house, the developers are still adopting the precast concrete method in their projects because the construction projects can be accomplished faster than 35% of total construction time approximately (Ngoenchuklin, 2014).

Moreover, regarding government projects, Hasiholan (2006) said that Thailand government announced to construct around 600,000 housing units during three years in 2004 for the citizens who were in low and medium-income group. Although some developers, contractors and designers proposed different housing construction methods, the National Housing Authority (NHA) of Thailand has approved the application of the Precast Large Panel Construction (PLPC).

Generally, the PLPC housing system comprises precast reinforced concrete panels, precast slab and foundations. Precast beams and columns are rarely used except for a few locations. Hasiholan (2006) revealed that using the PLPC system for a two-story house that included typical 2-3 bedrooms would take time (required for casting concrete, lifting and erection the components and completion of structure) only 2-4 days counting from the system starting date. It proved that how fast the PLPC system delivers a typical house comparing with conventional construction methods. Moreover, another advantages of using PLPC are mass production, no formwork for slab and vertical members, less overall cost, better quality control, no intensive labor requirement, modularization, durability and long term performance.

Currently, Thailand is one of the countries actively introduce the precast concrete construction. And the application of the precast concrete method in housing construction such as houses from affordable to mid-range prices, townhouses and low and medium-rise building becomes popular in Thailand.

2.4 Readiness, Maturity level and Readiness Models

Firstly, this section presents about the defination of readiness and maturity level. Then, readiness models, frameworks and tools from various industries are discussed. Those are Maturity Models, Benchmarking Models, Assessment tools, Capability

Maturity Models (CMMs), Readiness Frameworks, Models and Stages. The author conducted the literature review on those to get knowledge and understanding of the concept of readiness frameworks, models and assessment tools. From which, the author selected some frameworks and models as control model for the guidelines of factors and questionnaires to design and develop a framework in order to find the readiness for the application of precast concrete load-bearing wall.

2.4.1 Definition of Readiness

There are numerous definitions for the term 'readiness' that could be founded in the literature depending on the contexts. Readiness was interpreted as "the ability of an organization to adopt or implement new ideas, processes or products" (Burns & Stalker, 1961). According to Dada (2006), readiness was defined as " The measure of the degree to which a country, nation or economy may be ready, willing or prepared to obtain benefits that arise from ICT". On the other hand, Holt, Armenakis, Harris, and Feild (2007) revealed that "readiness is usually discussed in the context of managers' efforts to avoid or overcome employee's resistance to change". "Harvard University's Centre for International Development" (CID,2000) interpreted the term readiness as "the degree to which a community is prepared to participate in the networked world – a world in which everyone, everywhere, has the potential to reap the benefits of connectivity to the network". Moreover, as stated in Business Dictionary, the term readiness was defined as "State of preparedness of persons, systems, or organizations to meet a situation and carry out a planned sequence of actions". According to the definitions mentioned above, it is obvious that there is no precise and specific meaning for the definition of readiness and it depends on situations, context and users.

In this study, in general, the term readiness means the maturity of the organization or industry for the adoption of new methods or technology.

2.4.2 Maturity level

As reported by CMMI_Instirute (2019), maturity levels meant "a staged path for an organization's performance and process improvement efforts based on predefined sets of practice areas". For each maturity level, there is a predefined set of practice areas

that are provided a way to performance improvement. Each maturity level constructs based on the previous maturity levels by defining new functionalities.

Measuring maturity level is essential in the organization which intends to reach a higher level in their processes. The measurement enables information about and view of organization performance, process performance and product and service quality. In addition, measuring maturity level supports the clear vision of the issues in order to identify and manage risks and to detect and solve the problem in the early stage. Besides, it also helps in making the decision in time to achieve a better business outcome. Therefore, measuring maturity level is fundamental to improve process, product and service quality (Cardoso & van der Aalst, 2009).

For instance, Khalfan et al. (2001) created five maturity levels in the BEACON Model by referencing from RACE Model. Moreover, Bendi (2017) set up three levels in the Off-Site Construction (OSC) readiness framework to measure the maturity level of the construction companies. In addition, Carnegie Mellon University developed CMM model which could be applied to assess maturity of process and technology of an organization based on five maturity levels. In conclusion, in general, the maturity level is applied to measure the situation of the organization or industry for taking corrective action on time.

2.4.3 Review of Readiness Assessment Tools, Models and Framewrok

In order to develop a framework for assessing the readiness of the application of precast concrete load-bearing walls, an extensive literature review on readiness assessment tools and models in various areas was carried out. Among them, the following models and frameworks were cited frequently in previous papers. Those are “Readiness Assessment for Concurrent Engineering” (RACE) (Wognum, Stoeten, Kerkhof, & De Graaf, 1996); the “Process Model of Organization” (PMO) (Wognum et al., 1996); PMO and RACE Combination Model (PMO-RACE) (Wognum et al., 1996); “Project Management Process Maturity Model” (PM2) (Kwak & Ibbs, 2002); the “Capability Maturity Model” (CMM) (Aouad, Cooper, Kagioglou, Hinks, & Sexton, 1998); “Standardized Process Improvement for Construction Enterprises” (SPICE) (Finnemore & Sarshar, 2000); the “Benchmarking and Readiness Assessment for Concurrent Engineering in Construction” (BEACON) (Khalfan et al.,

2001); “Verify End-user e-Readiness using a Diagnostic Tool” (VERDICT) (Ruikar, Anumba, & Carrillo, 2006); MC Kinsey 7’s Model (Alshaher, 2013); Housing Developer BTS Readiness Framework (Yusof & Mohd Shafiei, 2011); Hierarchy of Effects Model (Buyer Readiness Stages) (Kotler & Keller, 2006); The IBSMS Organizational Readiness Framework (Musa et al., 2016)and E-Government Readiness (ERG) Framework (Azab, Kamel, & Dafoulas, 2009). Among these models, some were developed from various industries, such as construction, manufacturing, information technology and software. The overview discussion of the above listed models, tools and frameworks were presented in the following sections.

2.4.2.1 Readiness Assessment for Concurrent Engineering (RACE)

In the early ’90s. this tool was created at West Virginia University (USA) and it is broadly applied in the software engineering, electronics and automotive industries. RACE was useful to determine the level of performance for the product development process and improvement plan. Khalfan et al. (2001) revealed that this model could be adapted to apply not only in the construction but also in other industries. Moreover, this tool was basically developed for the assessment of concurrent engineering. There are two major components in the RACE-model: Process and Technology (Wognum et al., 1996). The Process component can be divided into ten elements (Customer focus, Product Assurance, Leadership, Team formation, Strategy development, Agility, Teams within the organization, Process focus, Management system and Discipline) and the Technology component can be divided into six elements (Project architecture, Application tools, Communication, Co-ordination, Information sharing and Integration).

2.4.2.2 The Process Model of Organization (PMO)

In order to analyse and determine an organization process and technology, PMO was invented. Morevoer, this model can be applied to analysis and design process and technology of an orginization. The objective of the application of this model was to identify bottlenecks that block the organization to gain its goal. Hence, the organization got the awareness and knew readiness stages to improve development process of the product (Wognum et al., 1996). Moreover, this model was widely used to detect major problem areas and the drivers for an organization business (Bendi,

2017). The PMO was conceptualized in terms of two components: organizational environment and process. The organizational environment component can be divided into two elements (task and general environment) and the process component into three elements (primary, control and support process).

2.4.2.3 A combination of PMO and RACE (PMO-RACE)

PMO-RACE is the combination of the PMO and RACE models. The researchers from the "University of Twente and Eindhoven University of Technology" (Netherlands) developed it in the mid '90s. De Graaf and Sol (1994) said that it was the combination of the strength of PMO that was the identification of key problem area, business drivers and the strength of RACE model that was the determining the level of performance for the product development process and improvement plan in order to make better process cycles and achieve the better model.

2.4.2.4 Project Management Process Maturity (PM)2 Model

In the late 90s, the (PM)2 model appeared at the University of California, Berkeley and it was developed to measure the project management (PM) levels of different organizations and industries. Hence, (PM)2 model is basically used to evaluate and position the current maturity level that assess the current PM practices and process of an organization. There are five levels for maturity of project managemnt process. Main objective of the application of the (PM)2 model is to apply like a reference point or a yardstick for an organization by adopting project management practices and processes. In addition, this model gives further suggestion to expertise and the use of technology of an organization. Moreover, this 5-Level (PM)2 model supports and guides in how to hire, motivate, retain competent people, necessary processes and requirements for achieving a higher project management maturity level (Kwak & Ibbs, 2002). There are eight components in this 5-Level (PM)2 model that covered the aspect of the model.

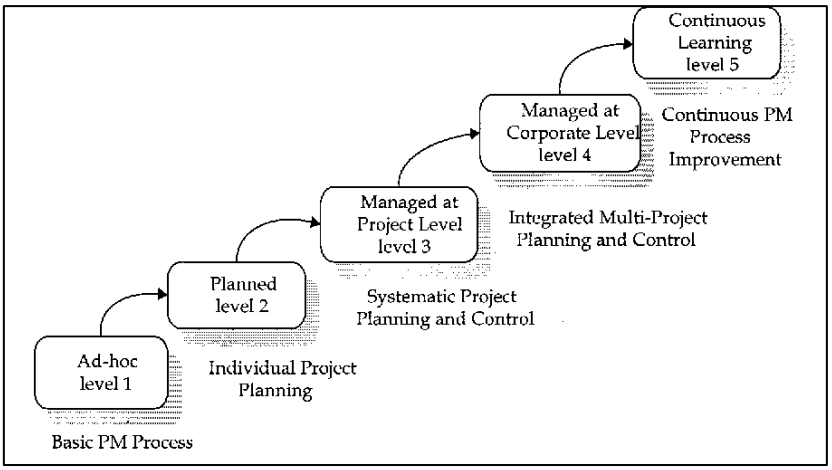

Figure 2.4: Project Management Process Maturity (PM)2 Model

(Kwak & Ibbs, 2002)

2.4.2.5 BEACON Model

Khalfan et al. (2001) developed the BEACON (Benchmarking and Readiness Assessment for Concurrent Engineering in Construction) Model to evaluate the readiness level of implementing concurrent engineering in the construction industry. This model was developed base on the RACE model and the survey could be conducted either in the form of an interview or questionnaire to collect the data. The BEACON Model was separated into four quadrants to describe four components: Process, People, Project and Technology. Each quadrant consists of relevant sub-components and critical factors to determine the maturity level of the construction industry. The 1st component consists of five sub-components regarding process to determine maturity level for construction organization and in 2nd component, there are four sub-components about people to determine the readiness for the team of the organization, while the 3rd component contains three sub-components concerning project to evaluate the client's needs. The last component contains five technological sub-components to evaluate the readiness of the organization regarding with utilization of advanced tools and technology. The main strength of this model is consisting of people and project elements when compare with RACE and other models. To determine the maturity level of each element of the organization, five levels were adopted from RACE Model and those are "Ad-hoc, Repeatable, managed,

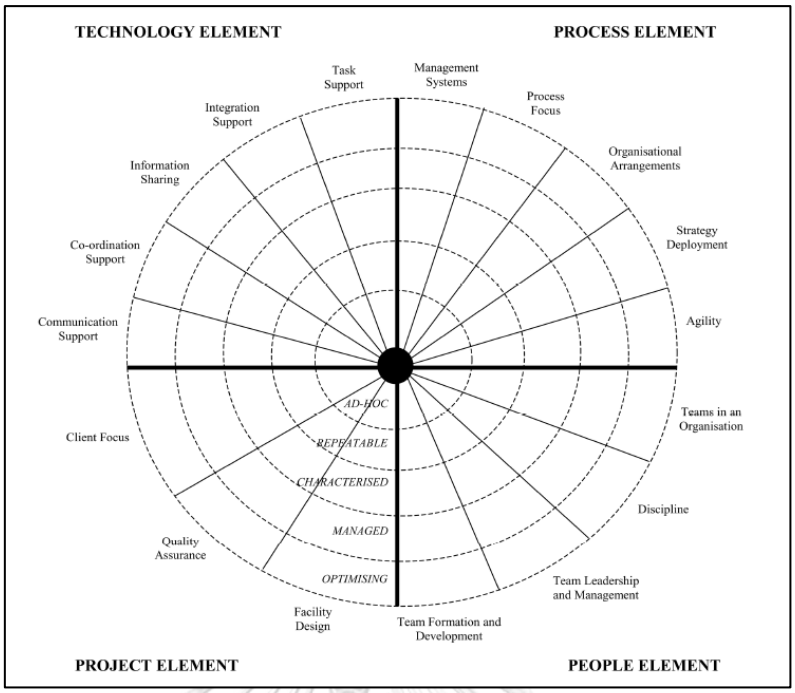

Figure 2.5: BEACON Model
(Khalfan et al., 2001)

Characterized and Optimizing". Among these five levels, the Ad-hoc level shows the lowest level whereas Optimizing level indicates the highest level for maturity of an organization (Khalfan et al., 2001).

2.4.2.6 CMM (Capability Maturity Model)

The fundamental mechanism of the CMM model is providing guidance to define processes position of software evaluation and development for the organization. The CMM model was created by the Software Engineering Institute at Carnegie Mellon University in order to manage software evaluation and development for the US government. The model was especially applied by the Department of Defense (Aouad et al., 1998). Khalfan et al. (2001) said that CMM could be applied to assess the readiness of a company's process and technology. This model has five maturity levels which are ad-hoc, repeatable, defined, managed and optimized stages (Aouad et al., 1998). CMM can be divided into two main components which are process and information technology.

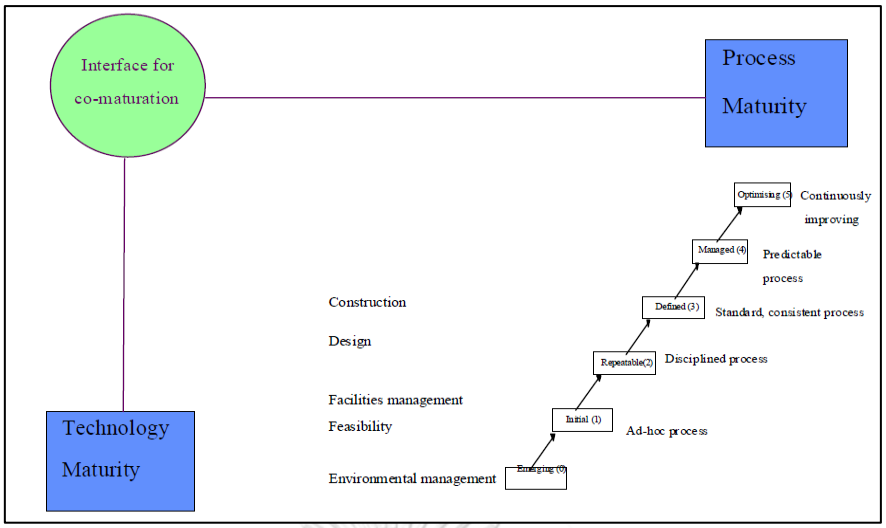

Figure 2.6: Capability Maturity Model (CMM)

(Aouad et al., 1998)

2.4.2.7 SPCIE

SPICE (Standardized Process Improvement for Construction Enterprises) was developed in the form of a questionnaire at the University of Salford, UK to assess the major construction process within an organization of the construction. The purpose of this tool is to improve the construction processes of an organization. This tool is fundamentally aimed to evaluate the maturity of the processes of an organization of the construction. It was developed based on the concept of CMM and there are five maturity levels in SPICE. Now it is currently at the stage of research prototype (Finnemore & Sarshar, 2000).

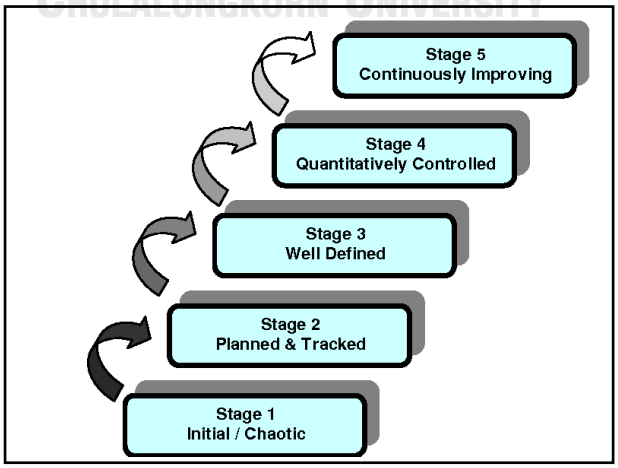

Figure 2.7: SPICE

(Finnemore & Sarshar, 2000)

2.4.2.8 VERDICT

VERDICT (Verify End user Readiness using a Diagnostic Tool) was designed to assess the readiness of the use of e-commerce technologies such as web-based collaboration tools for end-user companies in construction sector. The strength of the VERDICT model is that it is useful to measure the readiness level of the application of e-commerce in construction not only for company's organization but also for the departments of the company or individual groups of the department. There are three

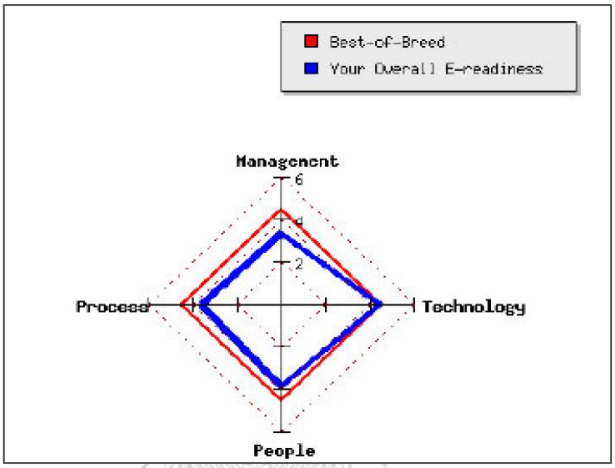

Figure 2.8: VERDICT Radar Diagram

(Ruikar et al., 2006)

levels of readiness in the VERDICT model which are red (Critical), Amber (Less critical) and Green (E-ready). These three levels of readiness (the traffic light indicator) highlights the strength and weakness of the organization and indicate the areas that require to improve. Moreover, this model determines construction companies' e-readiness in form of their four main components: Management, People, Processes and Technology, and shows the results of the department or company readiness not only in textual but also in graphical formats (Ruikar et al., 2006).

2.4.2.9 McKinsey 7S Model

In the early 80s, McKinsey 7s Model was developed by Tom Peters and Robert Waterman who were consultants at the McKinsey and Company consulting firm (Alshaher, 2013). This model was developed to assess how well an organization is positioned to attain its intended objectives. The model is mostly applied as an

organizational analysis tool to analyze and monitor the changes in the internal situation within an organization (Naipinit, Kojchavivong, Kowittayakorn, & Sakolnakorn, 2014). Moreover, Palatková (2011) revealed that McKinsey was very applicable for implementing a proposed strategy. In this model, there are seven elements all starting with the letter "S" as shown in Figure 2.11. These elements can be divided into two groups named hard S's (strategy, structure & systems) that are feasible and soft S's (skills, style, staff & shared values) are hardly feasible.

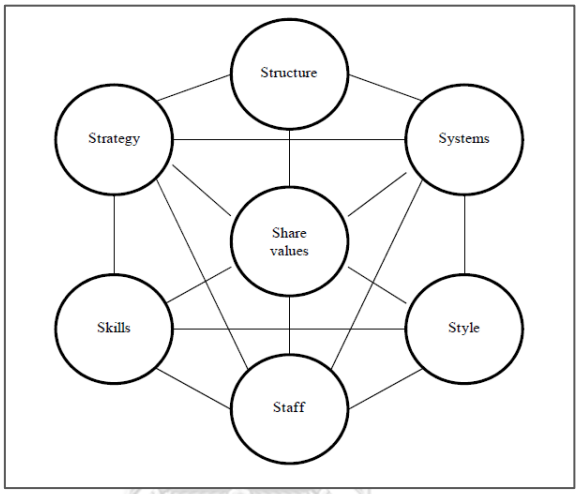

Figure 2. 1: McKinsey 7s Model
(Naipinit et al., 2014)

2.4.2.10 Housing Developer BTS Readiness Framework

This readiness framework was developed while identifying the factors that influence the readiness of housing developers to implement the BTS (Build Then Sell) which was a housing delivery system by Nor'Aini Yusof and Mohd Wira Shafiei from University Sains Malaysia. This framework can be divided into four main categories that affect the application of BTS readiness which are organizational readiness, resource readiness, market readiness and external support. The questionnaire was used as a data collection tool to measure the degree of readiness for each category. Interview was carried out with six experienced housing developers to ensure the validity of the model before the survey (Yusof & Mohd Shafiei, 2011). This framework was used to determine the housing developers' readiness in adopting the innovative system (BTS housing delivery system) that the Malaysian government had proposed.

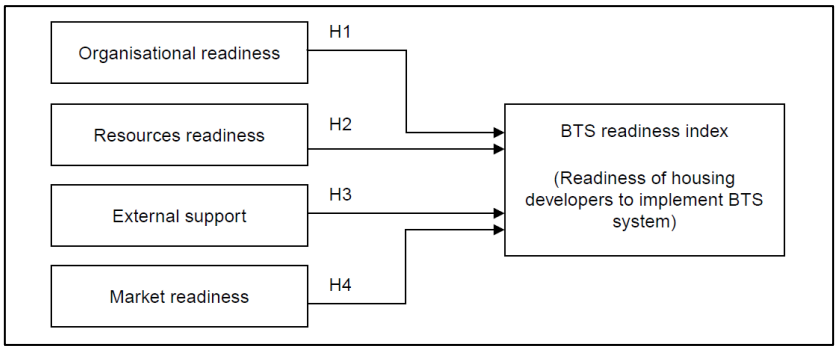

Figure 2. 2: Housing Developer BTS Readiness Framework

(Yusof & Mohd Shafiei, 2011)

2.4.2.11 Hierarchy of Effects Model (Buyer Readiness Stages)

The Hierarchy of Effects Model was developed by Robert J Lacidge and Gary A Steiner in 1961. This model was applied to attain an guideline series for advertising and promoting of a particular product and to develop each successive objective before a sale was ultimately made. Kotler and Keller (2006) mentioned this model as the buyer-readiness stage. In this model, there are six stages. Those are:

1. Awareness (existing customer awareness of target product or service)
2. Knowledge (customers' familiarity on target product or service)
3. Liking (rate of customers' favorable on target product or service)
4. Preference (customers' preference on target product or service to substitute for others by comparing quality, value and other features)
5. Conviction (customers' passion to buy or strong belief in target product or service)
6. Purchase – final activity of buying target product or service.

Roach (2006) applied this hierarchy of effect model to assess the readiness of the buyer for Biodiesel use.

2.4.2.12 IBSMS Organizational Readiness Framework

The Industrialized Building System Modular System (IBSMS) organizational readiness framework was developed by Musa et al. (2016) to improve the Malaysian construction industry and to achieve better readiness for construction organizations which execute IBSMS in Malaysia. This study identifed the readiness factors and

components which affect the application of IBSMS. The framework can be applied for all organizations or players in construction who desire to adopt or apply modular construction by tracking the factors of the framework. This framework was

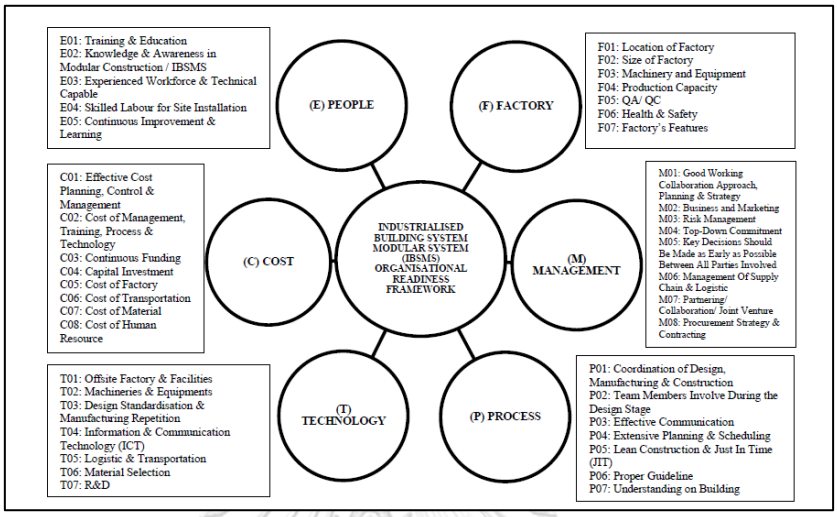

Figure 2. 3: The IBSMS Organizational Readiness Framework (Musa et al., 2016)

adapted from VERDICT Model and it was validated by a panel discussion with professionals first. Then, it was checked again by conducting a survey at the IBS seminar held by CIDB and a university. Fundamentally, the IBSMS organizational readiness framework can be divided into five elements: People, Process, Technology, Cost and Management and there are associated factors under each element. If IBSMS manufacturers want to adopt this readiness framework, the framework is needed to add one more element called Factory (Musa et al., 2016).

2.4.2.13 e-Government Readiness (EGR) Framework

This readiness framework was developed by Azab et al. (2009) to support for the evaluation on electronic government readiness in order to achieve e-government benefits in Egypt, emphasizing on internal factors that exist within a public organization. A case study research strategy was conducted to validate the framework. Qualitative data was collected by conducting an in-depth unstructured interview and semi-structured interview with top management and key person within the organization.

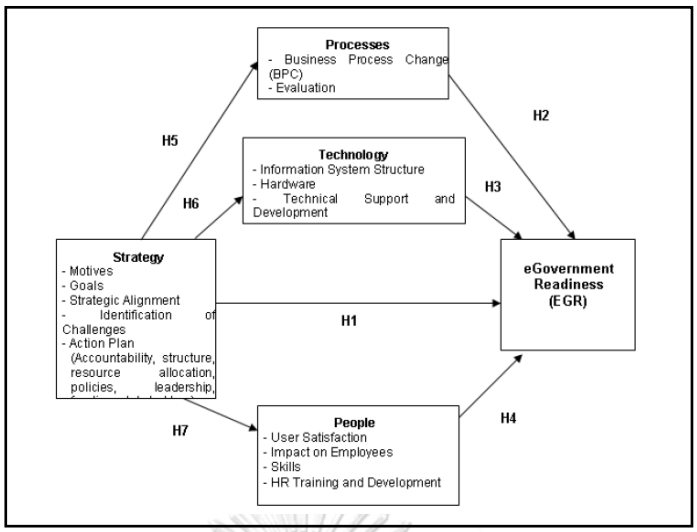

Figure 2. 4: e-Government Readiness (ERG) Framework (Azab et al., 2009)

This ERG framework adopted from the four-phase model of e-government (Baum & Di Maio, 2000) and this framework can be divided into four components: strategy, process, technology and people. In this study, Azab et al. (2009) assessed the weight of the four components that impacted to e-government readiness and relation between them.

2.4.4 Summary of the Readiness Model Review

Conducting a measurement of readiness has been proved that it is a successful approach before the adoption of new technology or innovation. A readiness assessment gives information about the weak points and provides the critical risks which can be happened while implementing a new technology within the organization. Through the literature review about readiness models, frameworks and tools mentioned in previous section, it could be concluded that most of the models, frameworks and tools were not developed specifically for precast concrete construction. Some were developed to evaluate the readiness of the organization, and some were developed to improve the process of product development and the application of the technology development in the organization. Moreover, some of the models, frameworks and tools were also applicable to the organizational environment to assist the readiness of development process. Among them, although IBSMS readiness framework seems to be possible in order to use for the readiness assessment of precast concrete application, there are some weaknesses to apply. IBSMS readiness

framewrok provides only components and factors that affect the use of modular system. It does not mention the methodology to assess the readiness of the organization and construction industry. Therefore, none of the models, tools and frameworks reviewed is suited to adopt directly in order to assess the readiness of construction industry and stakeholders for the application of precast concrete construction. Nevertheless, some of the models, frameworks and tools reviewed are possible to use as readiness assessment model for precast concrete after appropriate refinement and modification. Regarding the methods for data collection, the data can be obtained by using both interview and questionnaire methods for most of the models, frameworks and tools. And there are only few models and tools which can present the assessment result with diagram.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research framework and methodology used in this research for achieving the objective of the study. Qualitative, quantitative and triangulation methodology were used in this research. In addition, interview and questionnaire survey methods were applied for data collection. Moreover, Microsoft Office Excel were employed to analyze the data and calculate percentage of the readiness. The outcomes were aimed to develop a new readiness assessment model for adoption of precast concrete load bearing wall method and to evaluate the readiness of construction industry including major stakeholders for the application of precast concrete load bearing wall method in housing construction.

3.2 Research Framework

There were five major steps in the research methodology of this study. These steps were 1) conducting intensive literature review, 2) developing a conceptualized readiness model, 3) validation of the conceptualized model, 4) assessing the readiness of Thailand construction industries by carrying out as the first case study and 5) assessing the readiness of Myanmar construction industry by conducting as second case study. At the beginning, intensive literature review about precast concrete and definition of readiness, readiness assessment models, tools, and frameworks were conducted. Then, a conceptualized readiness model was developed based on document analysis and literature review. The validation of the conceptualized model was conducted by semi-structure interview with experts and the model was refined as their suggestions. In addition, the refined model diagram was checked by conducting a pilot test. Then, the readiness of construction industries for application of precast concrete construction were evaluated by conducting case studies in Thailand and Myanmar construction. Finally, two major research outputs which were a new readiness assessment model and maturity level of construction industries for the application of precast concrete were obtained. Figure3-1 presented an understandable structure of the research framework.

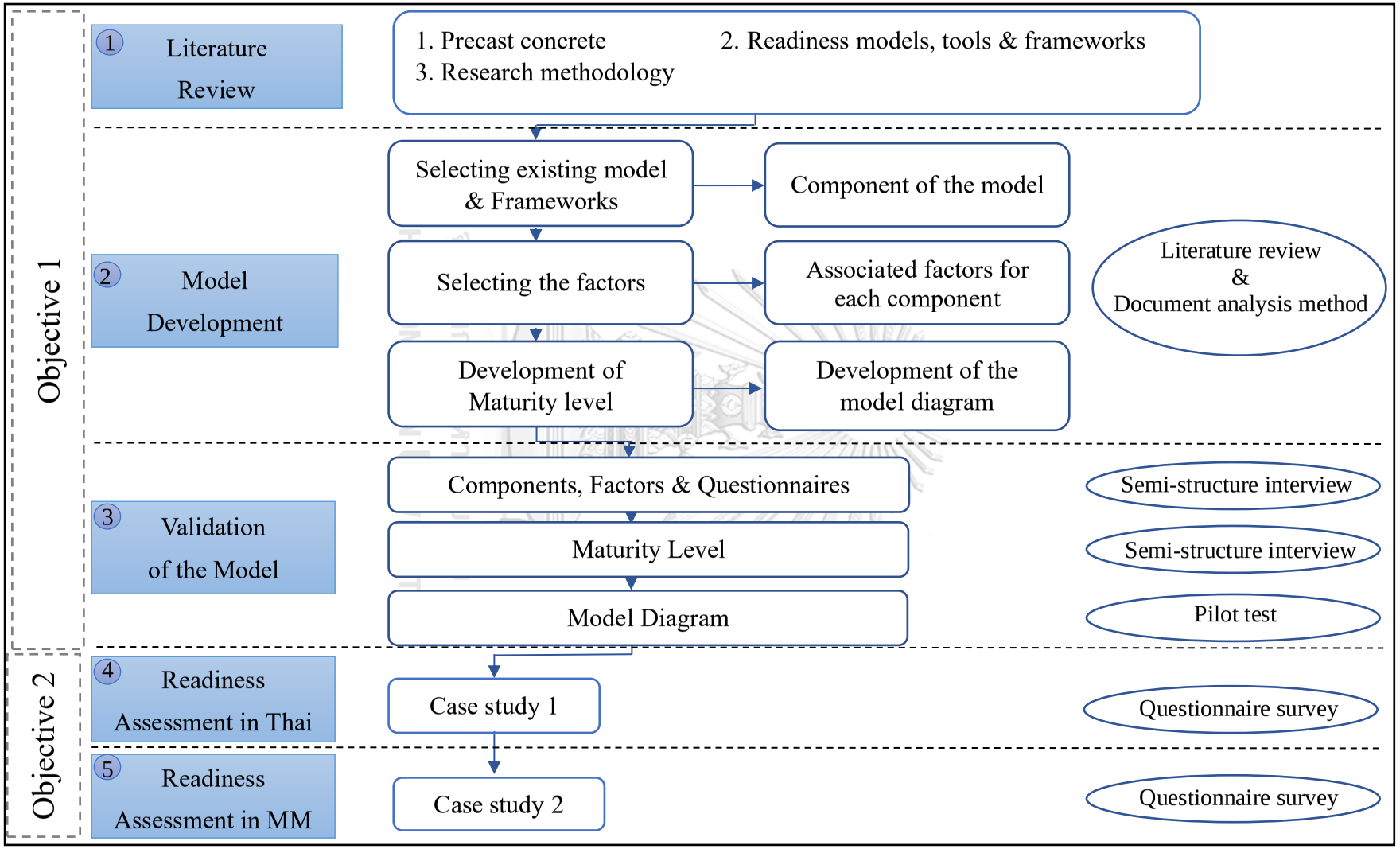

Figure 3.1: Research Framework

3.3 Research Methodology

The research methodology can be defined as the whole process of the research. It aims the process, tools and procedures of the research which are necessary to attain the data for the research (Mouton, 2011). Generally, there were three categories for research methodology in this research such as qualitative method, quantitative method and triangulation method which was combination of both qualitative and quantitative method (Khalfan et al., 2001). These methods were applied in this research and presented below.

3.3.1 Qualitative Research Method

The qualitative research method is useful for the question that cannot be addressed by the application of quantification. According to Bendi (2017), the qualitative research method was very useful for emerging research fields such as conducting research for adaptability and readiness of new things. Moreover, this method is enables to interpret the subjective cases, experiences and perspectives of the people (Grix, 2010). In this research, qualitative research method was chosen to apply in the development of a new readiness model for the application of precast concrete construction in housing industry.

3.3.2 Quantitative Research Method

The quantitative research method is a systematic and scientific examination of quantitative properties, phenomena, and their relationships. Generally, this method is measuring the numbers that gather the data from the people over a large geographical area (Bendi, 2017). Furthermore, according to Amaratunga, Baldry, Sarshar, and Newton (2002), quantitative research was pragmatic investigation of natural occurrences, facts and their relationships by applying statistical computation methods. In this current study, the quantitative research method was applied in case studies that are assessing the maturity level of adoption the precast concrete construction in Thailand and Myanmar construction industries.

3.3.3 Triangulation Method

Triangulation method means the application of not only qualitative but also quantitative research methods in a research. Triangulation method is appropriate

method for the research purpose that required to conduct the development of theories in qualitative approach and testing the theories in quantitative way since triangulation method makes the data become more reliable and valid because the strength of one can improve for another weakness (Ruikar et al., 2006).

In the present study, the triangulation method was applied since the aim of the present study was not only to carry out the development of a new readiness model but also the application of the model in construction industry by conducting case studies. Therefore, it was the most suitable method for the objectives of the current research.

3.4 Literature Review

The research was conducted an intensive literature review to draw an overview of the precast concrete industry and readiness assessment models. Conducting a literature review makes the researcher understand the majorities of previous works in the research field and improve the knowledge regarding the research area. In addition, Randolph (2009) revealed that "Conducting a literature review is a means of demonstrating an author's knowledge about a particular field of study, including vocabulary, theories, key variables and phenomena, and its methods and history". In this step, reviewing journal articles, thesis, textbooks and related publications are carried out. In this research, in order to develop conceptualized model, the literature review was mainly carried out regarding the application of precast concrete, readiness, readiness framework and research methodology based on document analysis. Document analysis is reviewing, thinking critically and analyzing current respective theories and papers.

3.5 Data Collection

Data collection is a process that requires to perform the communication between the researcher and the targeted respondents. Moreover, this process supports the researcher to determine and deal concurrently with essential contents and social processes (Bendi, 2017). There are numerous tools that are useful to collect the data. Among them, some are questionnaires, interviews which can be classified into structured, semi-structured and unstructured, panel discussion, literature review and observations. Choosing a suitable data collection method is depend on the research

question and approach, and it must fulfill to achieve the objectives and aim of the research. In this research, the semi-structured interview was used to obtain the data for the development of a new readiness model. And face to face questionnaires survey method were applied to obtain the data for readiness assessment of Thailand and Myanmar construction industry regarding the use of precast concrete load-bearing wall. The reasons for the use of face to face interview were to obtain reliable data, to avoid any missing data, misunderstanding and any confusion about the questionnaire.

3.6 Interview

The interview technique was adopted in this research for the first step of data collection. According to Zarinpoush (2006), "Interviews are an appropriate method when there is a need to collect in-depth information on people's opinions, thoughts, experiences, and feelings". In this study, semi-structure interview was conducted with five experts from famous companies that use precast concrete in Thailand in order to validate the model which covers the major stakeholders. These experts' positions are owner or above manager level of the organizations and they have been involved in precast concrete load-bearing construction at least five years and in construction ten years. A similar number of experts for interview were used in other studies to validate their theories. Khalfan et al. (2001) conducted an interview with three senior management staffs from three construction organizations to valid the BEACON model before the model was used to assess the readiness within construction industry. Moreover, Gan et al. (2017) interviewed to three experts to verify the factors for construction productivity analysis of pre-cast and conventional cast-in-situ projects. In addition, interviews with six professionals who have housing experiences were carried out in order to validate the content of housing developer BTS readiness framework before conducting the survey in industry (Yusof & Mohd Shafiei, 2011).

Zarinpoush (2006) presented that semi-structured interviews were well suited when the researcher needs to collect very detail information in a systematic manner from respondents. The interview format was divided into two sections. Section A was gathering the information about the profile of the respondents and section B was verifying the readiness model, factors, and questionnaire. Moreover, in section B, the

stakeholders' and its components' weight were acquired. The summary of interview for data collection is provided in Table 3-1.

3.7 Questionnaire

A questionnaire survey is applied as a tool to gather information for the data collection. According to HAW (2009), the questionnaire survey was one of the efficient tools for data collection when the researcher set up the questions systematically for the information and data that is required to evaluate the variable of interest. Moreover, Naoum (2012) stated that the questionnaire was a quick and useful method to conduct the data collection from a huge amount of population of respondents. Hence, the generalized result can be obtained.

In this research, the questionnaire was divided into two sections: sections A and B. Section A was information about the respondents' profile while section B was rating the scale of each stakeholder's readiness factors by Likert scale.

In this study, face to face questionnaires were conducted with five experts who are from contractor, developer and government organization in order to obtain the data for readiness assessment of Thailand construction industry regarding the use of precast concrete. These experts' positions are owner or above manager level of the organizations and have been involved in precast concrete load-bearing construction at least five years and in construction ten years. Although there was no participant from customer group, they know very well about the customer situation in Thailand and they can provide the data for customer readiness as a representative of customer, especially experts from developer group since all of experts were from top management level of the organization which have experience about the use of precast concrete in Thailand.

In order to assess the readiness of Myanmar construction industry, face to face questionnaires were carried out with 43 respondents. Among them, 15 respondents were from contractor companies, ten respondents were from developer companies, three respondents were from government organization and 15 respondents were from customer group. All respondents' positions from developer, contractor and government organization in Myanmar are above manager level while all of

respondents from customer group are from the house buyer list of real estate company.

In this study, the reliability test for the data that is obtained from the survey in Myanmar was not conducted since face to face questionnaire was applied in the survey in order to avoid misunderstanding and unreliable responses. Besides, a pilot test was conducted to make clear the questionnaire and to make sure the model's applicability based on expert's opinions. The summary of the questionnaire survey for data collection is shown in Table 3-1.

Table 3.1: The Summary of the Proposed Data Collection

Data Collection		**Content**	**Purpose**
Interview	Section A:	Information about the respondents' profile	For respondents' Background & experience
	Section B:	Verification of the readiness mode, factors, and questionnaire. Evaluation of the stakeholders and components weight value for the model	For research objective 2
Questionnaire	Section A:	Information about the respondents' profile	For respondents' Background & experience
	Section B:	Evaluation the readiness of the application of precast concrete construction in Thailand and Myanmar construction industry.	For research objective 3

3.8 Targeted Respondents

It is vital to determine the targeted respondents and the sample size to conduct the data collection. Bendi (2017) stated that the researcher should consider the research question type, available time, available resources, and the population characteristics before identifying on sampling size. Regarding sampling techniques, there are two major types of sampling techniques which are probability sampling and non-probability sampling (Cooper, Schindler, & Sun, 2006). Using a probability sampling technique requires a population list or exact sample list before the survey.

In this study, about the questionnaire survey, non-probability sampling technique known as snowball sampling was applied to select and identify respondents who are stakeholders in the Myanmar construction industry because to find the stakeholders list of Myanmar construction industry in advance is difficult. Target respondents from stakeholders were regulator, developer, contractor and customer (home buyer) from Myanmar. The respondents from the organization of regulator, developer and contractor have experience in construction industry and their positions are at least from senior level and above while respondents who represented for the customer were home buyers. According to basic principal for enough sample condition, at least 30 respondents from each stakeholder would be required for questionnaire survey to obtain different perspectives with enough sample. However, this study targeted 43 respondents which were 15 from contractor companies, ten from developer companies, three from government organizations and 15 from customer groups because limited time and cost were available, and the readiness assessment was just case study.

3.9 Data Analysis

In this research, data analysis was carried out after receiving the data from the interview and questionnaire survey. Kawulich (2004) mentioned that “data analysis is the process of reducing large amounts of collected data to make sense of them”. The analyses helped to evaluate the readiness percentage and maturity level for the application of precast concrete load-bearing wall in Thailand and Myanmar housing construction. After all the data were obtained, data analysis was conducted to get the mean score, weighted value, and percentage. In this study, “Statistics Package for

Social Science" (SPSS) and Microsoft Excel were adopted. SPSS was used to obtain the mean score from the survey questionnaire while Microsoft Excel was applied to calculate the percentage of the readiness.

3.4.1 Likert's Scale

A five-point Likert Scale Analysis was adopted to obtain mean value. Then, the percentage and weighted value of each component, stakeholders' group and construction industry were calculated. The percentages were used to evaluate the maturity of the construction industry, stakeholders' group and components of the groups. The mean score was calculated using the following formulae:

$$M(f_i) = \frac{\sum x_i}{N} \quad (1)$$

Where,

$M(f_i)$ = Mean Value of factor i

Σx_i = the sum of all of Likert's scale scores from respondents

N = the number of respondents

For instance,

Table 3.2: Mean Score

Component	Critical Success Factor	Frequency for Likert's Scale						Mean Score
		0	1	2	3	4	Total	
People	F1. Experience and technical capable workforce	0	3	7	15	5	30	2.73
	F2. Training and education	6	7	10	7	0	30	1.6
	F3. Knowledge and awareness	0	0	7	15	8	30	3.03

$$\text{Mean Score of F1} = \frac{(0\times 0)+(1\times 3)+(2\times 7)+(3\times 15)+(4\times 5)}{0+3+7+15+5}$$

$$= \frac{82}{30}$$

$$= 2.73$$

Next, the mean values obtained from the above formula were used in order to calculate the readiness percentage of the people component. The percentage was calculated using the following formula.

$$\text{Percentage of People component} = \frac{\sum_{i=1}^{n} M(f_i)}{\sum_{i=1}^{n} Max:M(f_i)} \times 100 \qquad (2)$$

$$= \frac{2.73+1.6+3.03}{4+4+4} \times 100$$

$$= 66.3\ \%$$

Where,

$M(f_i)$ = Mean value of factor i

$Max:M(f_i)$ = Maximum Likert's scale of factor i

Then, the readiness percentage value obtained from the calculation was applied in the evaluation of the maturity level of the construction industry and its stakeholders.

3.4.2 Mean Range Method

In this research, mean range method was applied to know the unimportant factors involved in the conceptualized readiness model. The researcher provided questionnaire form to rate the important level of the factors when experts were interview in Thailand. As reported by Naoum (2012), the mean value could be classified into five different classes as shown in Table 3.3 based on mean range formula below:

$$\text{Mean Range} = \frac{Largest Scale - Smallest Scale}{5} \quad (3)$$

$$= \frac{5-1}{5} = 0.8$$

Table 3.3: Mean Interpretation

Mean Value	Important Level
1.00 – 1.80	Unimportant
1.81 – 2.60	Slightly Important
2.61 – 3.40	Moderately Important
3.41 – 4.20	Important
4.21- 5.00	Very Important

Based on Table 3.3, the researcher eliminated the factors that obtain mean value lower than 0.81. The remining factors were used in the readiness assessment model.

3.4.3 Weight Calculation

The following formula was applied in order to determine weight value of each component. Weight value was calculated by using the mean values that obtain from the interview based on following formula:

$$Wi = \frac{M(f_i)}{\sum_{i=1}^{n} M(f_i)} \quad (4)$$

Where,

f_i = Factor i

$M(f_i)$ = Mean value of factor i

$\sum_{i=1}^{n} M(fi)$ = the sum of all factors' mean value

3.9 Conclusion

This chapter outlined the research methodology, research design, research development, data analysis tools/methods and research method for data collections used to accomplish the objectives of the research. The qualitative, quantitative research methodology and semi-structure interviews were adopted to develop a new readiness model and to determine the readiness of Thailand and Myanmar housing construction industry regarding precast concrete usage. The Statistical Package for the Social Sciences (SPSS) and Microsoft Office Excel were used for conducting the statistical analysis, data preparation and data transformation of the study.

The details of developing the factors, questionnaire and readiness model were discussed in Chapter 4. The results of qualitative research from the interview with experts to implement the verification of the readiness model were also discussed in Chapter 4. On the other hand, identification of the Thailand and Myanmar housing construction industries' readiness by using the questionnaire survey with five points Likert-scale will be presented in Chapter 5.

CHAPTER 4
DEVELOPMENT OF PRECAST CONCRETE CONSTRUCTION READINESS FRAMEWORK

4.1 Introduction

This chapter discusses the development of a readiness assessment model for the adoption of precast concrete load bearing wall construction in housing construction industry. The proposed model was named the 'Precast Concrete Construction Readiness Model' (PCCRM). Moreover, this chapter presents the factors used in this model and validation of the model.

To develop the model, this study conducted a comparative study about readiness models that are applicable to apply in assessing the readiness of construction stakeholders. And then, the best suited model and frameworks were chosen and integrated by refining to meet the requirement for assessment of precast concrete construction readiness. The next step was the factors that affect the application of precast concrete construction were selected from previous studies and maturity levels were developed. Finally, the model was validated by conducting semi-structure interview with experts and a pilot test for the applicability of the model.

4.2 Comparison of Readiness Models, Tools and Frameworks

A comparison table was developed to analyze the readiness models, tools and frameworks that mentioned in Chapter 2 and to take references for the model development. The table discusses about their characteristics under common criteria, which are:

- **Aspects encompassed:** identifies the major components considered in each model, tool and framework
- **Survey method:** discusses which methods are carried out for data collection in each model, tool and framework (questionnaires or interviews)
- **Application objective:** identifies the major objective of the application of each model, tool and framework

- **Appropriateness for application in precast concrete construction:** identifies the appropriateness of the models and tools to apply in the precast concrete construction industry since the main objective of this comparison is to determine the most suitable tool or model for developing a new readiness assessment model.

Table 4.1 illustrates the comparison about the models, frameworks and tools that were reviewed in Section 2.4.2.

After the comparison table was reviewed, it could be seen that some were developed to evaluate the readiness of the organization, and some were developed to improve the process of product development and the application of the technology development in the organization. Moreover, some were also applicable to the organizational environment to assist the readiness of development process. Therefore, it could be concluded that most of the models, frameworks and tools were not developed specifically for precast concrete construction.

Among them, IBSMS readiness framework seems to be possible in order to use for the readiness assessment of precast concrete application, but there are some weaknesses in those frameworks to use directly. That framewrok provides only components and factors that affect the use of modular system. And it does not include the methdology to assess the readiness of the organization and construction industry. Therefore, none of the models, tools and frameworks reviewed were suited to adopt directly for the aim of the research. Then, a readiness model which can assess precast concrete construction industry was needed to develop.

Table 4.1: Comparison of Readiness Models, Frameworks, Tools

Tools / Model	Aspects encompassed	Method of survey	Purposes of the application	Appropriateness to apply in precast concrete construction
"RACE" (Wognum et al., 1996)	• "Process" • "Technology"	"Interview" and "Questionnaire"	To determine level of the performance for product development process and improvement plan. Apply in the software engineering, electronic and automotive industries.	Many researchers have mentioned that RACE can be applied in construction after the model is modified specifically as its components are fundamental for many industries. However, it was mainly developed for concurrent engineering (CE). Therefore, after the criteria are specifically modified in this tool, it is also possible for use in precast concrete construction.
"PMO" (Wognum et al., 1996)	• "Organizational environment" • "Processes"	"Interviews", "Outline of past and current projects"	To detect bottlenecks which prevent the organization to gain its goal. Basically, it is used for analyzing and designing organization, its process and technology.	PMO is possible to use for precast concrete construction because it is basically used for analyzing and designing organization, its process and technology. But it should be noted that it mainly focuses on organization, its process and technology. Moreover, Khalfan et al. (2001) revealed that it seemed to be incomplete and had some limitations in using this tool.
"PMO-RACE" (Khalfan et al., 2000)	• Combination the aspects of "PMO" and "RACE"	"Interview" and "Questionnaire"	Combination of the strengths of two models.	Since RACE and PMO are possible to use for precast concrete construction as mentioned above, this model is under this research consideration. But the criteria of this model will be required to modified since it was mainly used for CE implementation process.

Table 4.1: Comparison of Readiness Models, Frameworks, Tools

Tools / Model	**Aspects encompassed**	**Method of survey**	**Purposes of the application**	**Appropriateness to apply in precast concrete construction**
"(PM)2" (Kwaak and Ibbs, 1997)	• "Planning to execute a project" • "Definition of project activities" • "Cost estimates for the project" • "Project Management (PM) process" • "PM-related data collection and analysis" • "Utilization of PM tools and techniques" • "Working as a team" • "Senior management support"	"Questionnaire"	To measure the project management (PM) levels of different organizations in industries. Hence, (PM)2 model is basically used to evaluate and position the current maturity level that assesses the current PM practices and process of an organization.	(PM)2 model is possible to use for precast concrete construction. But it should be noted that the model basically focuses on evaluating the maturity level of an organization for the application of PM practices and processes.
"BEACON" (Khalfan, 2001)	• "Process" • "People" • "Project" • "Technology"	"Interview" and "Questionnaire"	To evaluate the readiness level of implementing the concurrent engineering in construction industry.	Since BEACON was developed to use in construction industry, it is possible to use for precast concrete construction. But the model is needed to modify the criteria as it was specifically targeted for the use of concurrent engineering.

Table 4.1: Comparison of Readiness Models, Frameworks, Tools

Tools / Model	**Aspects encompassed**	**Method of survey**	**Purposes of the application**	**Appropriateness to apply in precast concrete construction**
"CMM" (Aouad et al., 1998)	• "Process" • "Information" • "Technology"	"Interview" and "Questionnaire"	To define the process position of software evaluation and process development of the organization.	CMM was basically developed for software industry. Therefore, the criteria of the model required to change to domain of precast concrete construction in order to use for precast concrete construction.
"SPICE" (University of Salford, UK, 1998)	• "Brief management" • "Project planning" • "Project tracking & Monitoring" • "Contact management" • "Quality assurance" • "Project change management" • "Risk management" • "Organization process focus" • "Organization process definition" • "Training program" • "Interdisciplinary co-ordination" • "Peer review" • "Technology management"	"Questionnaire"	Basically, this tool was developed to determine and improve the construction processes of an organization.	SPICE is appropriate to use for precast concrete construction since it was basically made to apply in construction industry. But it focuses only on construction process improvement within an organization.

Table 4.1: Comparison of Readiness Models, Frameworks, Tools

Tools / Model	Aspects encompassed	Method of survey	Purposes of the application	Appropriateness for apply in P.C construction
"VERDICT" (Ruikar, 2004)	• "Process" • "People" • "Management" • "Technology"	"Interview and Questionnaire"	To assess the readiness of the use of e-commerce technologies such as web-based collaboration tools for end-user companies in construction sector.	Since VERDICT was developed to apply in construction sector, it is possible to use for precast concrete construction. However, it was required to modify its criteria to meet with domain of precast concrete.
"McKinsey 7S" (Peters & Waterman, 1980s)	• "Structure" • "Strategy" • "Systems" • "Skills" • "Style" • "Staff" • "Shared value"	"Interview and Questionnaire"	It was developed to assess how well an organization is positioned to attain its intended objectives.	This model is applicable for the use of precast concrete construction after the criteria are set up to meet with domain of precast concrete application.
"Housing Developer's BTS Readiness Framework" (Yusof & Shafiei, 2011)	• "Organizational readiness" • "Resource readiness" • "Market readiness" • "External readiness"	"Interview and Questionnaire"	The framework was developed to identify the factors that influence the readiness of housing developers to implement the BTS (Build Then Sell) which is a housing delivery system.	This framework is appropriate to use in precast concrete construction, especially for developer since it was basically developed for developer in housing construction. However, the criteria were required to modified since the framework mainly focuses on the adoption of BTS system.

Table 4.1: Comparison of Readiness Models, Frameworks, Tools

Tools / Model	Aspects encompassed	Method of survey	Purposes of the application	Appropriateness for apply in P.C construction
"Hierarchy of Effects Model" or "Buyer Readiness Stages" (Lacidge & Steiner, 1961)	• "Awareness" • "Knowledge" • "Liking" • "Preference" • "Conviction" • "Purchase"	"Questionnaire"	To know market situation about customers for a specific product, to attain guideline series for advertising and promoting of a product and to develop each successive objective before a sale is ultimately made.	This model is not appropriate for the use of construction since the functions of this model are not related to domain of construction. However, the model is possible to apply for assessing the customer or buyer readiness in the use of precast concrete house.
"IBSMS Organizational Readiness Framework" (Musa et al., 2016)	• "People" • "Process" • "Technology" • "Cost" • "Management" • "Factory"	-	To improve the Malaysian construction industry and to achieve better readiness for organizations which execute IBSMS based on the factors and components of the framework.	This framework is appropriate for the use of precast concrete construction since precast concrete is one of the categories of IBS and this framework was developed for IBSMS.
"EGR Framework" (Azab et al., 2009)	• "Strategy" • "Process " • "Technology" • "People"	-	To support for evaluation on electronic government readiness in order to achieve e-government benefits in Egypt.	Since the function of the framework aims to assess readiness of government, it is possible for the use to assess government readiness in the adoption of precast concrete construction, after the criteria of the framework are modified.

4.3 Development of Conceptualized Readiness Assessment model

This study aimed to develop a precast concrete construction readiness model that can cover major stakeholder groups in construction industry. Hashemi (2009) revealed that early adopters and construction stakeholders which were designer, consultant, contractor, developer, manufacture, government and society were the most influential organizations in adoption of the new system. Therefore, a conceptualized readiness model was designed to cover the stakeholders who have majority roles in accepting the new technology such as precast concrete. They are contractors who build, developers who initiate, regulator who controls the law and customers who buy. In order to cover remaining stakeholder groups, the factors were considered in the model such as "availability of precast designers", "availability of precast consultant" and "availability of precast manufactures" in the industry.

The development of the conceptualized model was conducted in several steps. Firstly, literature review was carried out about critical success factors, drivers and hinderances of precast concrete to get understanding and to document about them. Furthermore, the existing readiness models, tools and frameworks that are available currently in the construction and other industries were reviewed to compare and select for the model development. For the contractor, IBSMS readiness framework was selected as a referenced framework because it was mainly developed to provide the components and factors which affect the readiness of contractor for the use of IBS modular system. EGR framework was the one that is appropriate for the regulator since this framework was developed to support the evaluation of government readiness and its core mechanism is similar to one of this study's requirements which is to assess the regulator readiness. The housing developer BTS readiness framework was chosen for the developer as the function of this framework was to evaluate the readiness of housing developers who adopt "Build Then Sell" system. The Hierarchy of effects model (Buyer Readiness stages) was a good model to take as a referenced model for customer readiness assessment for the reasons that it could be applied to evaluate buyer readiness stages and market situation for specific product. Moreover, Roach (2006) applied this model to assess buyer readiness for biodiesel use.

Then, all components of the selected model and frameworks were combined and tailored to meet with the requirements of the readiness assessment for the use of precast concrete method. In the next step, the factors which affect the readiness of precast concrete construction industry were selected from previous researches for all components of the conceptualized model. After that, maturity levels were developed for the proposed model based on ideas from BEACON model. Details about the factors and maturity levels of the proposed model were discussed in the following sections. These steps drove to the development of the conceptualized model called 'Precast Concrete Construction Readiness Model' (PCCRM) was depicted in (Figure 4.2). Finally, the model diagram (Figure 4.3) that can graphically present the readiness percentage which indicates maturity level of stakeholder and construction industry was created.

The conceptualized PCCRM model and its associated questionnaire could be divided into four legs to represent four stakeholder groups. The concept of the proposed PCCRM model which is depicted in Figure 4.2 is to obtain the readiness of construction industry, the readiness of major stakeholders which are the representatives of construction industry are required to identify. The stakeholders' readiness can be identified by evaluating the components and factors of the model.

Besides, the weight of stakeholders and components were considered when the readiness of construction industry was evaluated. The weight of stakeholders and components were obtained from the experts during the interview period of this study. The reason for considering the weight value in this study is the important level of each component that affects readiness of the different stakeholders and the influence of each stakeholder to the readiness of construction industry for adoption of precast concrete construction is not same. For instance, in Malaysia, the main driver for adoption of IBS in the construction industry is regulator group while contractor groups are reluctant to adopt that system because of the availability of intensive foreign labors with low wage.

4.3.1 Maturity Level

In this conceptualized PCCRM model, five levels which indicate the maturity of the construction industry and stakeholders were developed. The concept of maturity levels came from RACE, (PM)2, CMM, SPICE and BEACON model. All of them were also designed five levels for maturity of the organization. The maturity levels in this study were defined in the precast concrete context and the levels were depicted in Figure 4.1. These are primary level (0-20%), secondary level (20-40%), tertiary level (40-60%), readiness level (60-80%) and advanced level (80-100%).

The primary level indicates that the construction industry or the group is lack of knowledge and less understanding about precast concrete while advance level indicates that the construction industry is at optimal utilization of precast or the group is well practicing and looking for continuous improvement in precast concrete construction. The detail descriptions of these levels are presented below.

Primary level:	This level presents that the construction industry or the group is lack of knowledge and understanding about the adoption of precast concrete construction
Secondary level:	In this level, the construction industry or the group needs to improve several aspects for a successful adoption of precast concrete construction
Tertiary level:	It means the construction industry, or the group has some knowledge and experience, but certain aspects are still needed to improve for achieving the readiness level regarding the use of precast concrete construction.
Readiness level	This level shows that the construction industry or the group has adequate capability and are ready to adopt the precast concrete construction.
Advance level	It indicates that the construction industry is at optimal utilization of precast concrete and the group has know-how, high experiences and continuous improvement in the use of precast concrete construction

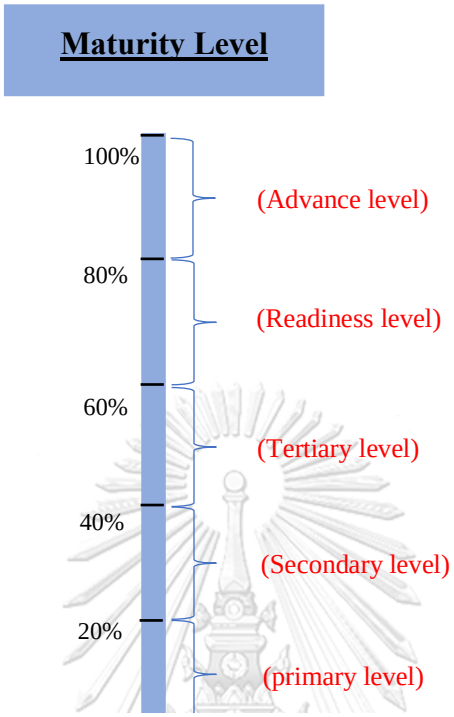

Figure 4.1: Maturity Level

4.3.2 Conceptualized PCCRM Model's Components and Factors

The aim of the proposed model was to evaluate the readiness of precast concrete construction industry by identifying the four major stakeholders' readiness. Therefore, this model was designed by four legs which represent for each stakeholder group. Each group has its associated components and factors. Before the factors of the model were identified for each leg, an intensive literature review about advantages, hinderances and critical success factors regarding precast concrete was carried out. Moreover, the factors were filtered to reduce from the high number to reasonable number. For instance, the factors which addressed same meaning with different labels were combined or eliminated. In the following section, the factors and components of each stakeholder group are identified and described.

4.3.2.1 Components and Factors of Regulator Group

One of the legs of the proposed model was designed with four components to cover the readiness assessment of the regulator for precast concrete adoption. Those components were process, technology, strategy and people. The concept of the first component 'Process' presents the practices, actions or activities of the regulator that supports for adoption of precast concrete method. 'Technology' signifies techniques, tools, methods and infrastructure that are required for the use of precast concrete. 'Strategy' implies any government plan and 'People' represents work forces, trainings and workshops related to people for achieving successful adoption of precast concrete construction. Under these four components, there are 20 associated factors for the regulator group. Table 4.2 presents the proposed readiness components and factors of the regulator group in conceptualized PCCRM model.

Table 4.2: Components and Factors of Regulator Group

Component	Factors	Descriptions
Process	1. Government policy Jiang et al. (2018), Rahimian et al. (2017),	The government policy is one of the major factors to establish demand for precast concrete. (e.g. Mandating to use precast concrete in projects or increasing daily wages of workers).
	2. Proper guideline Mohammad et al. (2014)	Proper guideline for precast concrete construction is necessary to support the smooth delivery process.
	3. Government Regulation Ting et al. (2019), Amar, Ismail, and Sahab (2012)	Government regulation is very important to uptake precast concrete construction and lack of regulation make stakeholder to be reluctant in the use of precast concrete.
	4. Transportation and Logistic Blismas and Wakefield (2009), Polat (2010)	Transportation and logistics regulated by regulator are necessary to consider because huge and heavy components are required to transport form the factory to the site.

Table 4.2: Components and Factors of Regulator Group (continued)

Technology	5. Research & Development (R&D) Zhang and Skitmore (2012)	Focusing on R&D is required to make testing, innovation and improvement of precast product.
	6. Design standardization & Codes Arditi et al. (2000), K. Kamar et al. (2009b)	Design standardization and codes for the precast system are essential to promote the precast system.
	7. Precast factory & Facilities Musa et al. (2016)	Knowledge about precast factory & facilities are essential in order to inspect the factory and permit the license.
	8. Machinery & Equipment Musa et al. (2016)	Knowledge about heavy machinery & equipment are essential to give permission for using at the site.
	9. Information & Communication technology K. Kamar et al. (2010)	The application of ICT can improve the use of precast concrete construction such as BIM technology.
Strategy	10. Tax incentive Khuan (2011)	Incentive and promotion provided by the government build up and increase the use of precast concrete system.
	11. Developing a road map Taherkhani, Saleh, Nekooie, and Mansur (2012)	Developing a road map for precast concrete system is one of the strategies to promote and increase the adoption of precast concrete.
	12. Promoting the education about precast concrete Arditi et al. (2000)	Promoting the education is required for the application of precast concrete since greater level of precision and skilled labors are required.
	13. Creating precast concrete exhibition Amar et al. (2012)	Creating precast concrete exhibition is one of the ways to promote the adoption of precast concrete system.
	14. Increment of government project using precast concrete Amar et al. (2012)	Adoption of precast concrete system can be promoted by increasing the use of that system in government projects.
	15. Environmental impact Taherkhani et al. (2012)	Application of precast concrete reduces environmental impact.

Table 4.2: Components and Factors of Regulator Group (continued)

People	16. Training and education K. Kamar et al. (2009b)	Training and education program about the precast concrete system for the government staff are necessary to achieve successful adoption of precast concrete.
	17. Knowledge & Awareness Mohamad et al. (2009)	Knowledge and awareness of the government staff about precast concrete system are essential for successful implementation of precast concrete.
	18. Experts & Profession in precast Luo et al. (2015)	The availability of qualified engineers specialized for precast in construction industry is important for adoption of precast system.
	19. Continuous improvement & Learning K. Kamar et al. (2010)	Successful implementation of precast concrete construction relies on the capability of the organization to improve the learning curve from one project to another project.
	20. Skilled workers in precast Thanoon et al. (2003), K. Kamar et al. (2010)	The availability of experienced and technical capable workforce for precast concrete in construction industry is crucial for adoption of precast concrete.

4.3.2.2 Components and Factors of Developer Group

In the PCCRM model, housing developer BTS readiness framework was selected as a reference model in order to cover the aspect for the readiness assessment of the developer group. According to this readiness framework, the developer group consists of four components which include Organization, Resource, Market and External support.

These four components can be identified as follows. ‘Organization’ refers to variety of organizational activities and behavior that shape the organization performance in its business. ‘Resource’ includes staffs, capitals and other assets that can be available from the organization or industry in order to drive the precast concrete construction. ‘Market’ refers to the condition of customer (buyer) and demand regarding the use of precast concrete method. ‘External support’ includes any support from the

government and financial institutions for the developers who adopt or plan to use precast concrete method in construction. There are total of 22 factors under these four components for developer group in PCCRM model. Table 4.3 gives information briefly about developer group's factors of the conceptualized PCCRM model.

Table 4.3: Components and Factors of the Developer Group

Component	Factor	Description
Organization	1. Firm's encouragement Yusof and Mohd Shafiei (2011)	Firm's encouragement to try new and better ways is one of the important factors to adopt new technology.
	2. Risk-averse culture Bendi (2017)	The approach of the organization in dealing with the existing negative image of the precast system.
	3. Continuous improvement & learning K. Kamar et al. (2010)	Successful implementation of precast concrete construction relies on the capability of the organization to improve the learning curve from one project to another project.
	4. Research & Development (R&D) Zhang and Skitmore (2012)	Focusing on R&D is necessary to conduct testing, innovation and improvement of the product.
	5. Knowledge & Awareness Mohamad et al. (2009)	Knowledge and awareness of the staff about precast concrete system is essential for successful implementation of precast concrete.
Resource	6. Experience & technical capable workforce for design Warszawski (2003), Mohamad et al. (2009)	The availability of workforces who are experienced and technical capable in design of precast concrete system is important for adoption precast concrete.
	7. Skilled labor for site Installation Thanoon et al. (2003), K. Kamar et al. (2010)	The availability of skilled labor for the installation of precast concrete components at the site is essential for adoption of precast concrete.

Table 4.3: Components and Factors of the Developer Group (continued)

	8. Training & Education K. Kamar et al. (2009b)	Training and education program about the precast concrete system for staff is necessary to achieve successful adoption of precast concrete.
	9. Availability of precast concrete manufacturers Mao, Shen, Pan, and Ye (2013)	The availability of a precast concrete manufacturer or supplier in the construction industry is crucial for the adoption of precast concrete construction.
	10. Machineries & Equipment Musa et al. (2016), K. Kamar, Alshawi, and Hamid (2009)	Availability of machinery and equipment to produce and assemble precast components is necessary for the application of precast concrete construction.
	11. Availability of experts and profession in precast concrete Luo et al. (2015)	The availability of qualified engineers specialized in precast concrete system is essential for the adoption of precast concrete construction.
	12. Availability of contractors specialized in precast system Polat (2010)	The availability of contractors specialized in precast concrete system is necessary for the adoption of precast concrete construction.
	13. Cost of factory Musa et al. (2016)	The overall cost to establish a factory for producing precast components is required to be considered.
Market	14. Market demand Mao et al. (2013), HAW (2009)	Adequate market demand is necessary to be feasible for the investment of the precast factory.
	15. Perception Hu, Chong, Wang, and London (2019)	Customer's perception on the precast concrete houses is important for the adoption of a precast concrete system.
	16. Willingness of customer Azhar, Lukkad, and Ahmad (2013)	Willingness of the customer on precast concrete house effects to the adoption of precast concrete in housing construction.
	17. Low-income groups buying power Yusof and Mohd Shafiei (2011)	Capability of low-income groups to buy precast concrete house is required to consider in order to use precast concrete in housing construction.

Table 4.3: Components and Factors of the Developer Group (continued)

	18. Medium-income group buying powerYusof and Mohd Shafiei (2011)	Capability of medium-income groups to buy precast concrete house is required to consider in order to use precast concrete in housing.
External Support	19. Government policy Jiang et al. (2018), Rahimian et al. (2017),	The government policy is one of the major factors to establish demand for precast concrete. (e.g. mandating to use precast concrete in projects or increasing daily wages of workers).
	20. Incentive & Promotion Khuan (2011)	Incentive and promotion provided by the government for using precast concrete system build up the use of precast concrete construction.
	21. Environmental impact Taherkhani et al. (2012)	Application of precast concrete reduces environmental impact.
	22. Government Regulation Ting et al. (2019), Amar et al. (2012)	Rules and regulations are very important to uptake precast concrete construction and lack of regulation makes stakeholder to be reluctant in the use of precast concrete.

4.3.2.3 Readiness Components and Factors of Contractor Group

In the contractor group, there are five components which are Process, People, Management, Technology and Cost, and each of these components has its own factors. These components were adopted from the IBSMS readiness framework which are selected to cover the aspects for the readiness assessment of contractor group in previous section. 'Process' refers to a series of tasks to execute precast concrete construction and it is vital to understand deeply overall process of precast concrete construction. 'People' signifies work forces and the programme related with people for achieving successful adoption of precast concrete construction such as training, continuous development and learning. 'Management' involves any activities that guide the direction of an organization business and lead the organization to achieve successful adoption and implementation of precast concrete construction. 'Technology' implies techniques, tools, methods and infrastructure that are required for production and execution of precast concrete construction. 'Cost' issue is almost the most important one required to consider when adopting precast concrete

construction. It includes various possible cost in order to execute precast concrete construction.

Under these components, there are 26 associated factors which are selected from previous papers, literature review, model and frameworks chosen in this study. The following Table 4.4 shows generally about components and its associated factors of the contractor group in the conceptualized PCCRM model.

Table 4.4: Components and Factors of the Contractor Group

Component	Factor	Description
Process	1. Coordination in design, manufacturing & construction Warszawski (2003)	Coordination in design, manufacturing, and assembling are crucial in the implementation of precast concrete construction.
	2. Effective communication Musa et al. (2016), Blismas and Wakefield (2009)	Effective communication is an important factor to make sure no miscommunication among project members.
	3. Extensive planning & Scheduling K. Kamar et al. (2010)	Since the production of precast components in early-stage and precise installation are required, extensive planning and scheduling are important.
	4. Understanding the building Regulations Musa et al. (2016)	It is essential to make sure that precast concrete construction complies with building regulation of the city.
	5. Proper guideline Mohammad et al. (2014)	The proper guideline involves an important role to be smooth delivery of the precast concrete construction process.
	6. Lean construction & Just in time (JIT) Musa et al. (2016)	Application of lean construction and just-in-time concept in precast concrete construction is required in order to achieve successful adoption of precast concrete construction.

Table 4.4: Components and Factors of the Contractor Group (continued)

People	7. Training & Education K. Kamar et al. (2009b)	Training and education program about the precast concrete system for staffs are necessary as greater level of precision, technique and skill labors are needed for precast construction.
	8. Knowledge & Awareness Mohamad et al. (2009)	Lack of knowledge and awareness of the precast concrete advantages and concepts are one of the major factors that make players feel difficult to adopt precast concrete.
	9. Experienced & Technical capable workforce Warszawski (2003), Mohamad et al. (2009)	The availability of workforces who are experienced and technical capable in precast concrete system is important for adoption precast concrete.
	10. Skill labor for site installation Thanoon et al. (2003), K. Kamar et al. (2010)	The availability of skilled labor for the installation of precast concrete components at the site is essential for adoption of precast concrete.
	11. Continuous improvement & Learning K. Kamar et al. (2010)	Successful implementation of precast concrete construction relies on the capability of the organization to improve the learning curve from one project to another project.
Management	12. Good working collaboration, planning & strategies Lu and Liska (2008), Y.-h. Pan (2007)	Good working collaboration, planning, and strategies resolve the problem that may happen due to lack of sharing information in both manufacturing factories and construction sites.
	13. Business approach Bendi (2017)	The clear business and strategic plan for precast construction are necessary, including effective cost combination for achieving successful adoption of precast construction.
	14. Top-down commitment K. Kamar et al. (2010), Musa et al. (2016)	Top managements and general labors are required to work as a team and conduct the job as their commitment.

Table 4.4: Components and Factors of the Contractor Group (continued)

	15. Management of supply chain and logistic Ismail et al. (2012), K. Kamar et al. (2009b)	Management of supply chain and logistics are important for precast concrete construction because they involve all stages of precast concrete construction implementation.
	16. Risk Management Bendi (2017)	Risk management is crucial in precast concrete practices because it provides contingency measures to deal with unexpected cases.
	17. Procurement strategy K. Kamar et al. (2010)	Procurement strategy for the precast concrete project is required to deliver the project smoothly.
Technology	18. Precast factory & Facilities Musa et al. (2016)	Availability of precast factory and facilities to produce precast components are essential.
	19. Machinery & Equipment Musa et al. (2016)	Availability of machinery and equipment to produce and assemble precast components are crucial for the application of precast concrete.
	20. Information & Communication Technology (ICT) K. Kamar et al. (2010)	ICT is an effective supporting tool to improve project delivery processes in the implementation of precast construction.
	21. Logistic & Transportation Blismas and Wakefield (2009), Polat (2010)	Logistic and transportation are required to follow the highway regulation of the city.
	22. Research & Development (R&D) Zhang and Skitmore (2012)	Focusing on R&D is necessary to conduct testing, innovation and improvement of precast products.
Cost	23. Effective cost planning, control & management Musa et al. (2016)	For achieving successful adoption, effective cost planning, control and management in precast concrete construction are vital.
	24. Cost of management, training, process, and technology Musa et al. (2016)	It is crucial to consider cost of management, training, process, and technology for the implementation of precast concrete construction.

Table 4.4: Components and Factors of the Contractor Group (continued)

	25. Cost of materials & Equipment Musa et al. (2016)	Cost of materials and equipment used to produce and assemble precast concrete components are required to consider.
	26. Cost of transportation Musa et al. (2016)	It is essential to account for the transportation cost of the precast component from the production yard to the construction site.

4.3.2.4 Readiness Components and Factors of Customer Group

In order to encompass the aspects for the readiness assessment of the customer group, the Hierarchy of effects model (Buyer Readiness stages) was adopted for the PCCRM model in previous section. Based on the Hierarchy of effects model, the customer group of PCCRM model includes six components that are awareness, knowledge, liking, preference, conviction and purchase. 'Awareness' refers to existing customer awareness of precast concrete houses. Firstly, the customer must have awareness of the precast concrete houses. 'Knowledge' indicates customers' familiarity on precast concrete houses. The customer must have knowledge about precast concrete houses at a minimal level such as what advantages precast concrete houses offer. 'Liking' is the rate of customers' favorable to precast concrete houses. In this stage, customers have not only familiarity but also positive attitude toward the house. 'Preference' represents customers' preference on precast concrete houses. In this stage, strong and favorable attitudes to precast concrete house are appeared inside of customers' mind. 'Conviction' means customers' passion to buy or strong belief in precast concrete house. In this level, passion or strong belief push the customer to purchase the precast concrete house. 'Purchase' signifies activities regarding buying the precast concrete house. In this final stage, customers reject other houses that can be replaceable to the precast concrete house and buy the precast concrete house.

There are total 18 factors under these six components. These factors were selected based on previous papers, literature review, models and frameworks. Table 4.5 presents the customer group's components and factors of the conceptualized PCCRM model.

Table 4.5: Components and Factors of the Customer Group

Components	Factors	Description
Awareness	1. Durability Hamill et al. (2006), Asamoah, Ankrah, Offei-Nyako, and Tutu (2016)	Using precast concrete methods can reduce the defects on-site and improve the durability of precast concrete components since they are inspected before transport to the site.
	2. Fire resistance PCI (2019), VanGeem (2006)	Precast concrete house offers better fire resistance than normal houses since concrete walls resist to fire and heat as well as prevent the spread of smoke and flame.
	3. Overall cost saving Arif et al. (2012)	Using precast concrete system can save the overall construction cost of the project directly and indirectly from the area such as less labor requirement and time saving.
Knowledge	4. Environmental impact Bendi (2017)	The adoption of precast concrete construction can minimize waste generation at the site.
	5. Earthquake resistance Arditi et al. (2000), WELLS (2020), (Crisafulli et al., 2002)	Precast concrete load bearing wall house offers superior earthquake resistance if joints are well designed because its structure is like rectangular frame structure that can resist more lateral load than normal frame system.
	6. Time saving Polat (2010)	Application of precast concrete system can boost up construction speed.
	7. Smooth and ledge free finishing WELLS (2020)	Precast concrete house offers smooth and ledge free walls that are easy to clean.
Liking	8. Low life cycle cost Asamoah et al. (2016)	The life cycle cost of the precast concrete house is lower than the normal house.
	9. Quality Asamoah et al. (2016)	Precast concrete house offers better quality than normal traditional house since it is produced under control environment and inspected before transporting to the site.

Table 4.5: Components and Factors of the Customer Group (continued)

	10. Thermal insulation Chen, Okudan, and Riley (2010), PCI (2019)	Precast concrete house offers better thermal insulation than normal house because concrete density provides thermal performance by maintaining more uniform indoor temperatures.
	11. Benefit WELLS (2020), VanGeem (2006)	Precast concrete construction offers more benefits than the normal traditional construction method such as resistance to fires, natural disasters and insects.
Preference	12. Appearance HAW (2009),	Appearance of precast concrete house is one of the factors effecting the development of precast concrete.
	13. Function PCI (2019)	Precast concrete house offers better function such as fire resistance, sound control and prevent air leakage.
	14. Acoustic insulation Asamoah et al. (2016), PCI (2019)	The precast concrete house offers better acoustic insulation than normal house because concrete panel offers an intrinsically solid house that has high acoustic performance.
Conviction	15. Price Reed and Mills (2007), HAW (2009)	Price is one of the important factors that affect the house buyer decision.
	16. Life safety and health PCI (2019)	Precast concrete building can offer life safety and health because it is resilient structure that resists to fire, blast, hurricane and improve indoor air quality. Customer perception on the safety for staying in precast concrete house is important for purchasing decision of house buyer.
Purchase	17. Availability of loan Reed and Mills (2007)	Availability of loan from the bank to buy the house is an important factor for house buyer.
	18. Experience on Purchasing Roach (2006)	Experience on purchasing the product is one of the factors to know the customer readiness.

4.3.3 The PCCRM Model's Questionnaires

The questionnaire used in precast concrete construction readiness model (PCCRM) was developed based on the factors of the model to assess the readiness of construction stakeholders and industry. The development of the questions under each factor of each component for each group was based on coverage of precast concrete construction principles and issues which have been published in previous studies.

In the PCCRM's questionnaire, three types of five-point Likert scale were used based on the question for the assessment scale as shown in Table 4.6. The PCCRM questionnaire can be applied to determine the readiness of the construction industry and construction stakeholders for the adoption of precast concrete construction.

Table 4.6: Five-point Likert Scale Description

Likert Scale	0	1	2	3	4
Description	Never	Not sure	Sometime	Most of the time	Always
	Unavailable	Not sure	Sometime available	Mostly available	Always available
	Disagree	Not sure	Slightly agree	Agree	Strongly agree

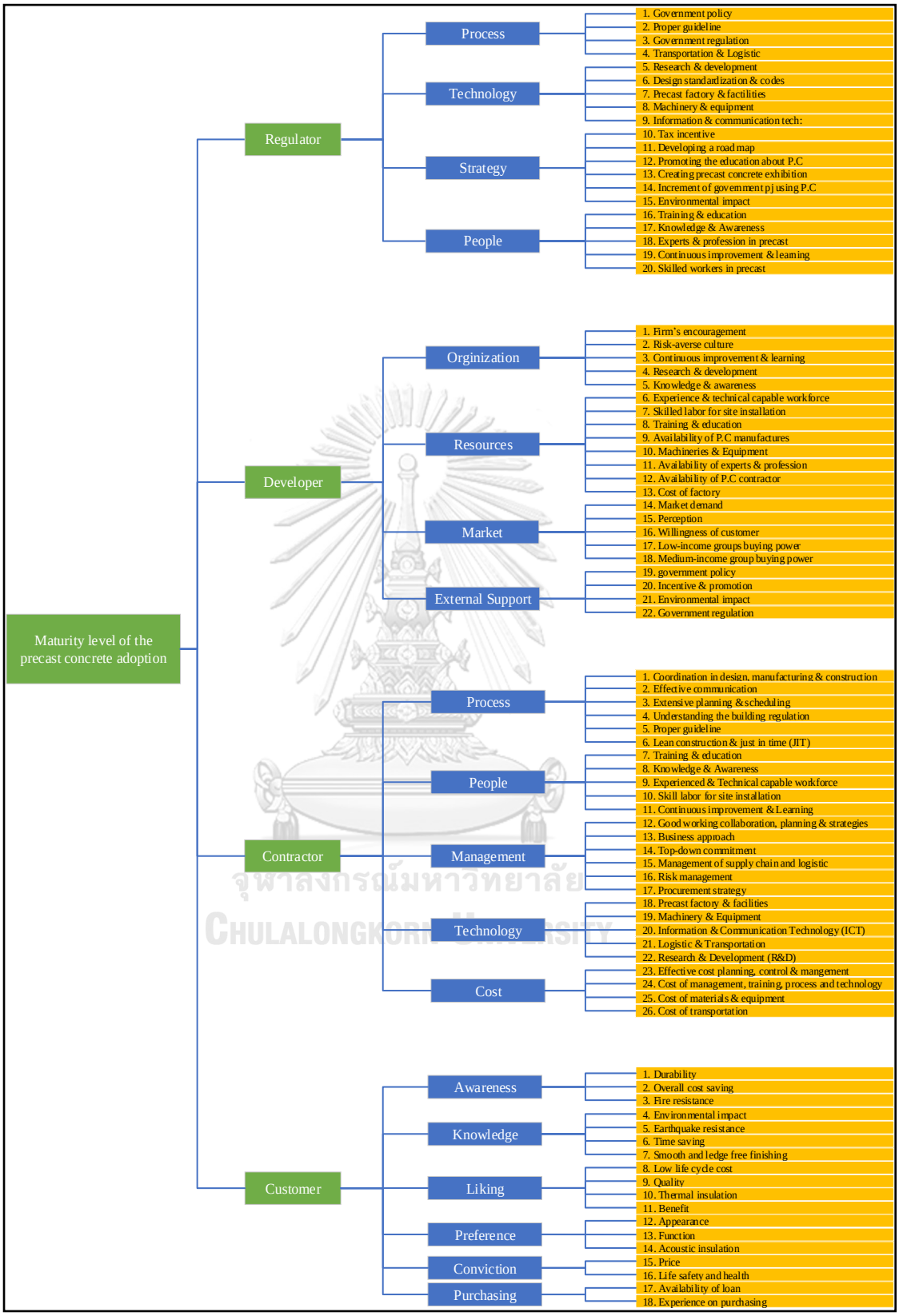

Figure 4.2: Conceptualized PCCRM Model

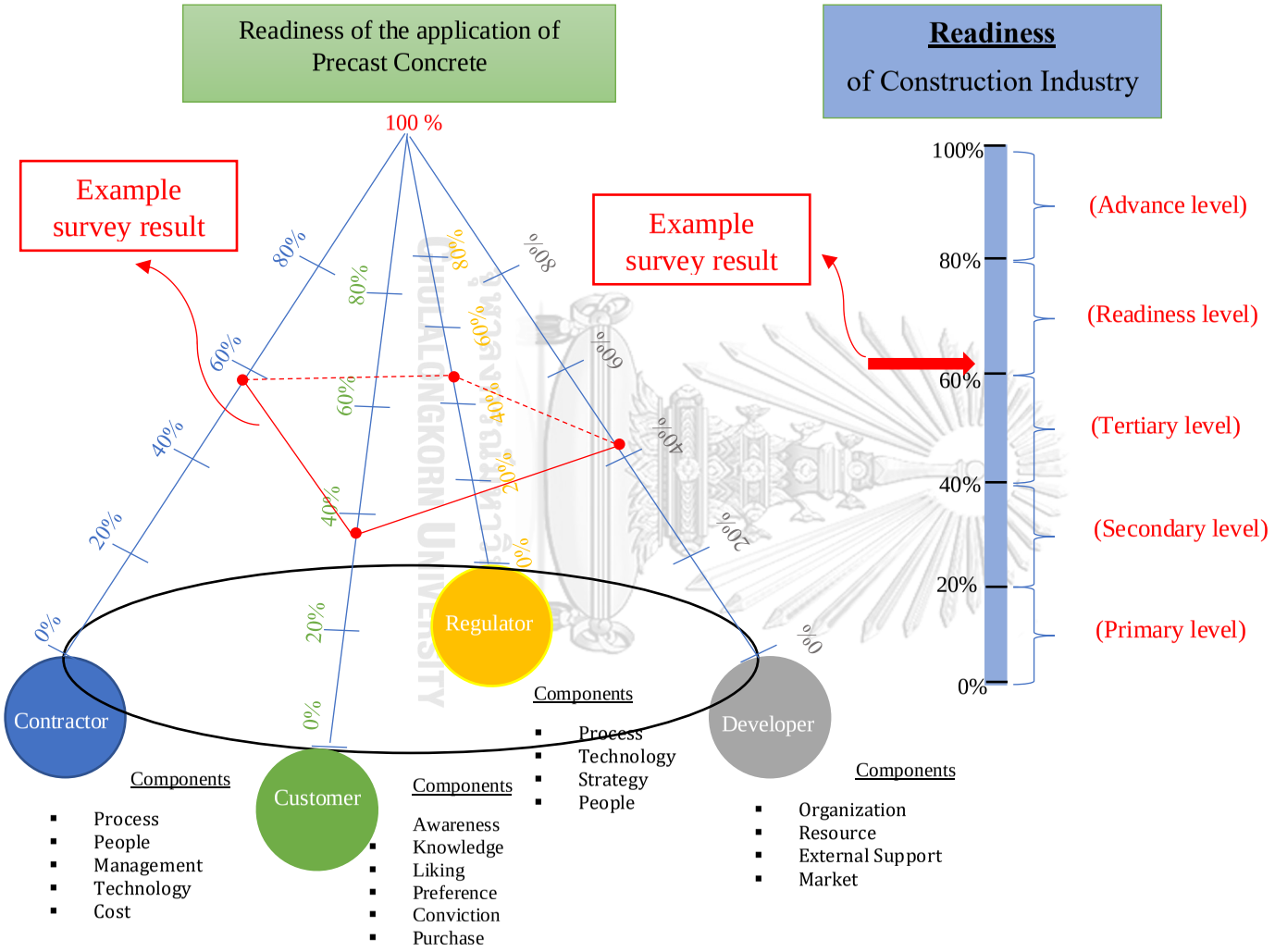

Figure 4.3: Conceptualized PCCRM Model's Diagram

4.4 Validation of Conceptualized PCCRM Model

To validate the conceptualized PCCRM model, this study conducted interview section with five experts who were working for famous precast concrete companies in Thailand. These five experts had at least more than 10 years of experience in construction industry and five-year experience in precast concrete construction. A similar number of experts for interview were interviewed in other studies to validate their assumptions. Khalfan et al. (2001) and Gan et al. (2017) carried out interviews with three experts and Yusof and Mohd Shafiei (2011) conducted interviews with six experienced housing developers in order to validate their assumptions. In this study, the purpose of conducting the interviews with experts were not only for validating the conceptualized model but also for several purposes. Those were

- To obtain important level of each factor, weight value of each component under respective stakeholder groups and weight value of each stakeholder
- To validate the conceptualized model, its associated factors and survey questions
- To obtain recommendation for future refinement for the model, its factors and survey questions

The duration of each interview was taken approximately one and half hours. All the experts were provided with the interview question form (Appendix A). The interview was designed as a semi-structured interview involving four major questions. In the first part of question, the experts were asked to answer the important level of the factors that can measure the readiness of the associated stakeholders. Hence, unimportant factors lower than 1.81 mean score were to eliminate from the model and weights of the components of each stakeholder group were calculated based on the scores that the experts answered. As an example, mean value of each factor under regulator group based on the responses of experts obtained from the interview were shown in Table 4.7. For other groups, mean values based on the experts' responses were presented in Appendix.

According to five experts' answers, unimportant factors which are lower than mean value of 0.81 from regulator group was F.9 "Information and communication

technology (ICT)" because they said "*ICT is not essential at the beginning state of the adoption of precast concrete construction and only hard copy of 2D drawings are required to submit to the government in order to obtain the permit for construction at this moment*". And unimportant factors under customer group were F.2 "overall cost saving", F.5 "time saving" and F.6 "low life cycle cost" from customer group because respondents said "*F.2, F.5 and F.6 are not the factors that customers focus and interest in buying the precast concrete house*". Mean value of all factors under other groups were greater than 1.81.

Table 4.7: Expert Scores for Important Level of Regulator Factors

		No.	Factors	Expert					Mean
				E1	E2	E3	E4	E5	
Regulator	Process	1	Government policy	2	2	2	3	1	2.0
		2	Proper guidelines	2	2	2	3	1	2.0
		3	Government regulation	5	5	5	4	4	4.6
		4	Transportation and logistic	2	4	3	4	3	3.2
	Technology	5	Research & Development (R&D)	2	4	2	3	1	2.4
		6	Design standardization & Codes	4	3	3	3	4	3.4
		7	Precast factory & Facilities	2	1	2	3	2	2.0
		8	Machineries & Equipment	2	5	4	3	2	3.2
		9	Information and communication technology (ICT)	2	2	2	2	1	1.8
	Strategy	10	Tax incentive	2	2	2	2	2	2.0
		11	Developing a road map	2	4	3	3	1	2.6
		12	Promoting education about precast concrete	2	3	2	3	3	2.6
		13	Creating precast concrete exhibition	2	2	2	2	2	2.0
		14	Increment of government project using precast concrete	2	5	3	5	4	3.8
		15	Environmental impact	2	2	2	2	2	2.0
	People	16	Training & Education	2	2	2	2	2	2.0
		17	Knowledge & Awareness	2	2	3	3	3	2.6
		18	Experts and professional in precast	3	3	2	3	3	2.8
		19	Continuous improvement & learning	2	3	3	3	3	2.8
		20	Skilled workers in precast	2	5	3	3	3	3.2

After four unimportant factors were eliminated, 84 factors remained and were used in refined PCCRM model shown in Figure 4.3. Among 84 factors, 19 factors are under regulator group, 22 factors are for developer group, 26 factors are allocated for contractor group and 17 factors are for customer group. Based on the mean values of remaining factors under each group, weight value of components was calculated.

Firstly, average mean value of each component was evaluated. For instance, in order to calculate 'process' component average mean score (see in Table 4.8), the score which is the sum of all factors' mean values under the process component is divided by total number of factors under the process component. Then weight value of each component was calculated by using the formula mentioned in Section 3.4.3. The components' weight values under regulator group are presented in Table 4.8.

Table 4.8: Components' Weight Value Under Regulator Group

		No.	Factors	Expert Mean Score	Component average mean score	Component weight
Regulator	Process	1	Government policy	2.000	2.950	0.271
		2	Proper guidelines	2.000		
		3	Government regulation	4.600		
		4	Transportation and logistic	3.200		
	Tech:	5	Research & Development (R&D)	2.400	2.750	0.253
		6	Design standardization & Codes	3.400		
		7	Precast factory & Facilities	2.000		
		8	Machineries & Equipment	3.200		
	Strategy	9	Tax incentive	2.000	2.500	0.230
		10	Developing a road map	2.600		
		11	Promoting education about precast concrete	2.600		
		12	Creating precast concrete exhibition	2.000		
		13	Increment of government project using precast concrete	3.800		
		14	Environmental impact	2.000		
	People	15	Training & Education	2.000	2.680	0.246
		16	Knowledge & Awareness	2.600		
		17	Experts and professional in precast	2.800		
		18	Continuous improvement & learning	2.800		
		19	Skilled workers in precast	3.200		
				51.200	10.880	1.000

The summary for the weight value of each component under each stakeholder is presented in Table 4.9. And detailed calculation of the components' weight and score of the factors answered by experts are shown in Appendix C.

Table 4.9: Summary for the Components' Weights of Each Stakeholder

Industry	Stakeholder	Components	Component's Weight	Sum of components' weight
Precast Concrete Construction	Contractor	Process	0.200	1.000
		Management	0.205	
		People	0.196	
		Technology	0.198	
		Cost	0.201	
	Regulator	Process	0.271	1.000
		Technology	0.253	
		Strategy	0.230	
		People	0.246	
	Developer	Organization	0.265	1.000
		Resource	0.271	
		External Support	0.281	
		Market	0.184	
	Customer	Awareness	0.179	1.000
		Knowledge	0.120	
		Liking	0.169	
		Preference	0.159	
		Conviction	0.166	
		Purchase	0.206	

In addition, the experts were asked to answer important level of construction stakeholders in the adoption of precast concrete construction in order to calculate weight values of each stakeholder. Summary for the weight values of stakeholders are shown in Table 4.10. Detail calculation of the stakeholders' weight and score of the questionnaire answered by experts were shown in Appendix C.

The second part of question aimed to ask the suggestions for additional factors that are required to add more for each stakeholder group. Regarding additional factors, one expert advised to add more factors in the customer group which were "Attitude" and "Payment system". The expert said, "*customer attitude is an important factor*

Table 4.10: Summary for the Weight Values of Stakeholder

Stakeholders	**Mean Score**	**Stakeholders' weight**
Regulator	3.00	0.203
Developer	4.60	0.311
Contractor	3.20	0.216
Customer	4.00	0.270
	14.80	1.00

for the adoption of precast concrete construction in housing. In some countries, precast concrete construction cannot be applied because of customer's negative attitude on the precast concrete houses. Regarding payment system, availability of good banking system or credit payment system for buying precast concrete houses also effect to the readiness of house buyers".

The third part of question focused to ask about the appropriateness of components with their associated factors and survey questions of the proposed model. All the experts agreed on appropriateness of the relation between the components and their associated factors. Moreover, the experts pointed out some questions which had unclear meaning to modify them before they were applied in construction industry.

In the fourth part of question, the experts were questioned about the adequacy of the number of maturity levels for assessing the construction industry's readiness and appropriateness of each maturity level's description. All the experts agreed on the proposed number of maturity levels, and one of the experts suggested that "*5 levels for human assessment are acceptable but it will be better to find the references for proposed number of levels in order to be a reliable model*". Concerning with the description of the model's maturity levels, all the experts stated the description of these levels were acceptable to apply for assessing the application of precast concrete readiness of construction industry. However, one of the experts recommended to describe more detail about the description of these maturity levels.

All the recommendations and suggestions from the interview were incorporated with the conceptualized model and it was refined accordingly. The refined PCCRM model with weight value of components and stakeholders is presented in Figure 4.4. And the

interpretation of the model's maturity levels which have been modified according to the experts' comments is presented in Table 4.11. Furthermore, the final PCCRM model diagram is shown in Figure 4.5 which depicts the readiness percentage of stakeholders and construction industry.

After the PCCRM model was refined, a pilot test was carried out with a person who is not only an expert in precast construction but also an academic person for the applicability of the questionnaire and evaluation the maturity level of construction industry. The purpose of this test was to ensure and analyze the model's applicability and effectiveness before the assessment model is applied in the construction industry.

Table 4.11: Refined PCCRM Model Maturity Level

Maturity level	**Description**
Primary	This level presents that the construction industry or the stakeholder does not have plan for adoption of precast concrete construction in housing projects. And the stakeholders are lack of knowledge and less experiences about the advantages of precast concrete construction.
Secondary	In this level, there are many barriers needed to be solved by improving several aspects for successful adoption of precast concrete construction in the housing projects and for attaining customer's interest and preference in precast concrete house. Just few customers prefer and interest it. Regulator needs to improve and provide for several aspects to be successful adoption of precast concrete in construction industry.

Tertiary	It means the construction industry, or the stakeholder has some knowledge and experience about precast concrete. And stakeholders are possible to be capable for adoption of precast concrete construction, but the team may be struggle in the adoption. In this level, certain aspects are still needed to improve to achieve the readiness level in the use of precast concrete construction. Some customers prefer and interest in precast house and regulator still needs to improve and provide for certain aspects.
Readiness	This level shows that the construction industry or the stakeholders have adequate capability and are ready to adopt the precast concrete construction for the projects and most of the customers interest and prefer the precast concrete house. Regulator provides adequate supports and plans for the adoption.
Advanced	It indicates that the construction industry is at optimal condition in the use of precast concrete construction. All stakeholders mostly apply the precast concrete method in their projects, and they have know-how, high experiences and continuous improvement regarding the adoption of precast concrete.

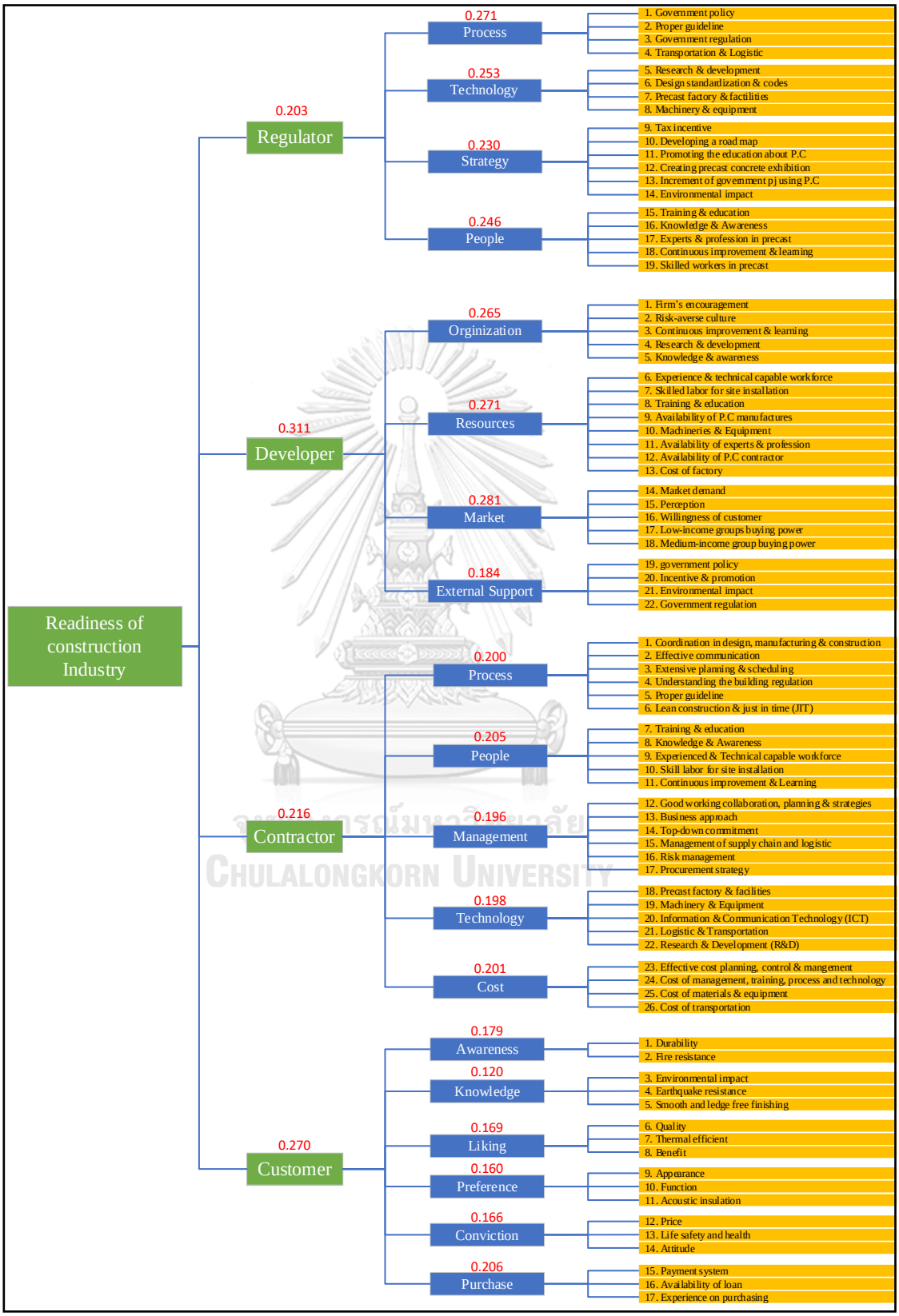

Figure 4.4: PCCRM Model

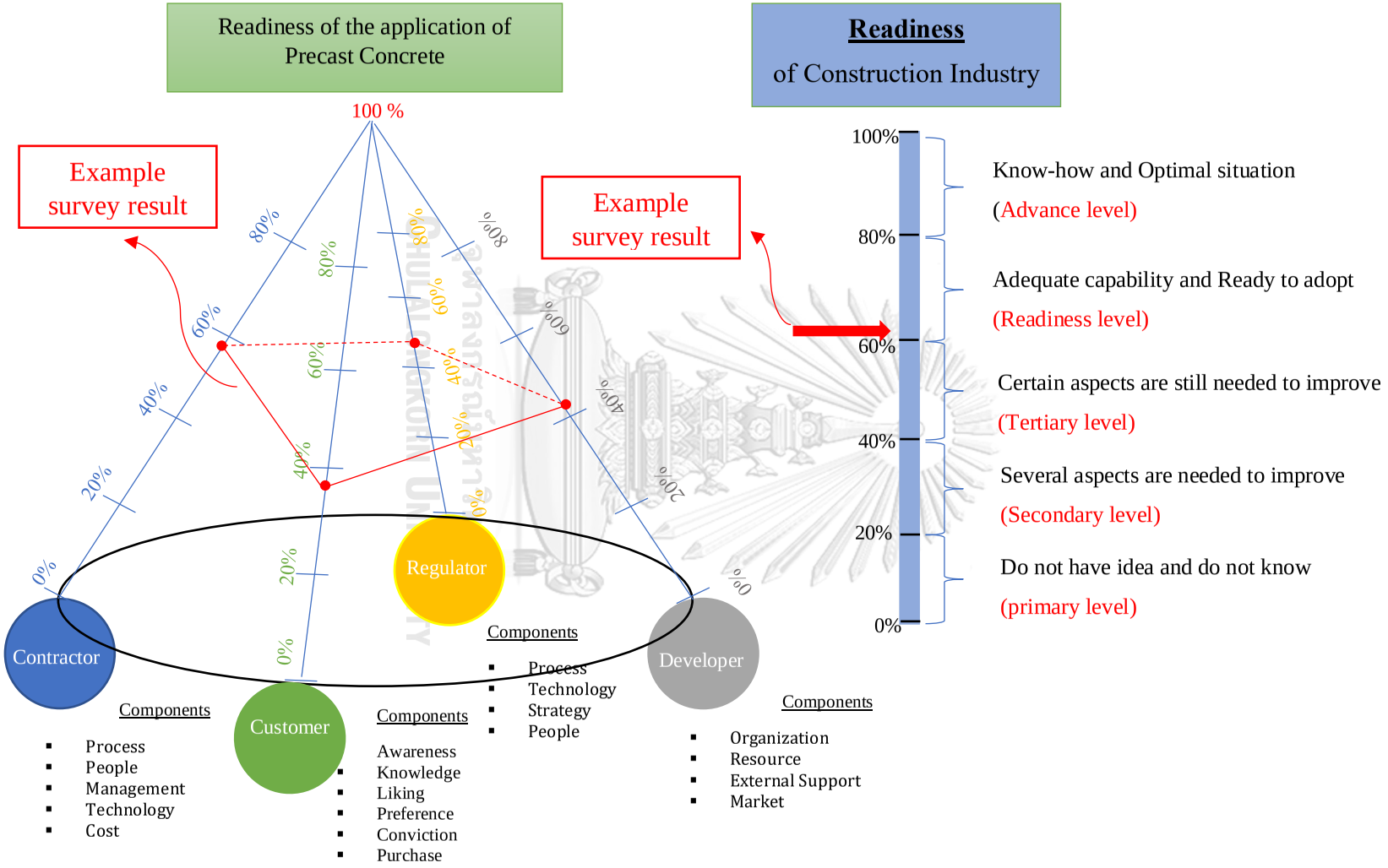

Figure 4.5: PCCRM Model's Diagram

4.5 Discussion

The development of the precast concrete construction readiness model (PCCRM) is vital and useful for the organization that wants to adopt the precast concrete construction. The strengths of the PCCRM model are described below:

- The PCCRM model can be applied not only for the construction industry but also for self-assessment on four major stakeholders: Contractor, Developer, Regulator and Customer in order to know the readiness.
- Application of PCCRM model provides strengths and weaknesses of the construction stakeholders (organizations) and industry regarding the use of precast concrete
- This model and its associated factors are specifically tailored to meet the needs of precast concrete
- When another construction method or product is adopted, this model can also be used by revising the factors to new factors suited the new context.
- Application of the PCCRM model for the readiness assessment of construction stakeholders (organization) and industry will provide the guidelines to achieve the successful adoption.
- In order to obtain data for readiness assessment, the survey could be conducted by structure interview form or by electronic questionnaire form alternatively.

It should be noted that lack of fulfillment for those readiness factors does not mean the construction industry or the organizations (stakeholders) cannot execute or implement precast concrete construction. It may be possible to be capable for the use of precast concrete construction, but the team might be struggled in the adoption.

4.6 Conclusion

This chapter presented the development of the precast concrete readiness model. At first, the comparison table of readiness models, tools and frameworks was constructed in order to choose the most suitable models and frameworks as references for developing a new model. Then, a conceptual framework and maturity level for a new

readiness model were developed. Hence, the key factors were identified for the proposed model by conducting an intensive literature review about advantages, hinderances and critical success factors of implementing precast concrete construction based on document analysis. Finally, the conceptualized model was refined according to the feedbacks from the semi-structured interview and a pilot test was conducted in order to validate the model.

To be concluded, this chapter discussed the vital stages involved in the development of precast concrete readiness framework. Finally, the precast concrete construction readiness model (PCCRM) was presented. Thus, the objective one and two of the research were successfully achieved in this chapter. The following chapter discussed assessment of the construction industry by conducting this PCCRM model on the two case studies.

CHAPTER 5
ASSESSMENT OF THE APPLICATION OF PRECAST CONCRETE CONSTRUCTION READINESS

This chapter addresses the last objective of the research that is to evaluate the readiness of construction industry by conducting PCCRM model on two case studies. Firstly, this chapter presents readiness assessment of Thailand construction industry to check applicability of the model. Then, readiness assessment of Myanmar construction industry is discussed. The objectives of the assessment are to assess the readiness of the construction industry for the application of precast concrete construction, to identify the sectors that need to improve for achieving successful implementation of precast concrete construction and to explore the PCCRM model applicability.

5.1 Readiness Assessment for the Application of Precast Concrete Construction in Thailand

In order to assess Thailand construction industry readiness including major stakeholders' readiness, a case study was carried out. In this case study, five experts who were above manager level of the organizations (government, contractor and developer) and had been involved in precast concrete load-bearing construction at least five years and in construction ten years were selected. These five experts were as representatives to answer overview about the current situation and practices of stakeholder groups in Thailand regarding the application of precast concrete construction. Although there was no participant from customer group in the interview, since all of experts were from top management level of the organization which had experience about the use of precast concrete in Thailand, they knew very well about the customer situation in Thailand. So, they could provide the data for customer readiness as a representative of customer group, especially experts from developer group. The assessment results of the model which were obtained from the interviews sections provided the readiness percentage and maturity of major stakeholders and construction industry. Moreover, the result could provide to determine the strength and weakness of stakeholders' components.

In the questionnaire, five-point Likert scale (0, 1, 2, 3 and 4) were applied. This questionnaire was provided in the interview section with the experts. After responses for the questionnaire were received from the experts, these scores were converted into percentage for each component and stakeholder in order to assess the maturity level and plot on the PCCRM Model diagram. For instance, as shown in Table 5.1, mean score of 'Process' component which has six questions is obtained 17.6 by summing the mean score of six questions under the component. If all responses for each question under the 'Process' component gain maximum score of '4', the mean score of the component which has six questions would be 24. Then, the readiness percentage of 'Process' component would be 62.9% (17.6/24 x 100) out of possible 100%. The remaining components' percentage of the stakeholders were also calculated in the same way.

Moreover, weight values of each stakeholder and its components described in Chapter 4 were considered when the readiness percentage and maturity of construction industry are evaluated. The reason for considering the weight value of stakeholders and its components was the important level of each component that affects to readiness of the stakeholder was different. In the same concept, the influence of each stakeholder to the readiness of construction industry for adoption of precast concrete construction is not the same.

The following explanation was the calculation method for the readiness percentage of stakeholders. As shown in Table 5.1, there were five components under contractor group and readiness percentage of these five components which were calculated as the method explained in above paragraph were 62.9%, 75%, 72.5%, 45% and 77.5% respectively. And their weight values evaluated in Chapter 4 are 0.200, 0.205, 0.196, 0.198 and 0.201, respectively. Then, the readiness percentage of regulator group would be 72.4% (62.9x0.200 + 75x0.205 + 72.5x0.196 + 45x0.198 + 77.5x0.201) out of possible 100%. In the same way, the readiness percentage of construction industry would be calculated by using stakeholders' readiness percentage and their weight values.

Finally, the readiness percentage of construction industry and stakeholders were plotted in the PCCRM model diagram in order to provide virtual representation of

their overall readiness. The following sections discussed the case study which was about the readiness of stakeholders and construction industry of Thailand.

5.1.1 Readiness of Contractor Group

According to five experts' responses, a summary of the assessment results is shown in tabular form. Table 5.1 gives information about the readiness percentage of the contractor organization in Thailand for the application of precast concrete construction.

Table 5.1: A Summary of Readiness Assessment Result for Contractor Group

		Factors	Component weight	Experts					Mean Score	Component mean score	Readiness of component (%)	Readiness of Contractor (%)
				E1	E2	E3	E4	E5				
Contractor	Process	F1	0.200	2	2	3	3	3	2.6	17.6	62.9%	72.4%
		F2		2	3	2	3	3	2.6			
		F3		4	2	4	2	3	3.0			
		F4		3	3	4	3	2	3.0			
		F5		4	2	3	3	3	3.0			
		F6		4	4	2	3	4	3.4			
	People	F7	0.205	4	2	3	3	3	3.0	15.0	75.0%	
		F8		4	2	3	2	2	2.6			
		F9		3	2	3	4	4	3.2			
		F10		4	3	4	4	3	3.6			
		F11		3	2	2	2	4	2.6			
	Management	F12	0.196	3	2	3	3	3	2.8	17.4	72.5%	
		F13		3	3	3	2	4	3.0			
		F14		3	2	3	2	3	2.6			
		F15		4	3	3	4	3	3.4			
		F16		3	2	2	3	3	2.6			
		F17		4	3	3	2	3	3.0			
	Technology	F18	0.198	4	4	3	4	3	3.6	14.8	74.0%	
		F19		4	3	4	4	3	3.6			
		F20		2	1	2	3	3	2.2			
		F21		4	3	4	4	3	3.6			
		F22		2	1	2	2	2	1.8			
	Cost	F23	0.201	2	3	2	3	4	2.8	12.4	77.5%	
		F24		2	3	2	2	2	2.2			
		F25		4	3	4	4	4	3.8			
		F26		4	3	4	4	3	3.6			

The readiness percentage of the organization and each component were evaluated according to the questionnaire responses. The assessment result gave information that the percentage of all components under contractor organization were between 60% and 80% which meant that their maturities were at 'Readiness level'. In addition, the maturity of contractor organization of Thailand construction was also at the

'Readiness level'. This concludes that the contractor organization is ready and capable to apply the precast concrete construction. The factors that needed to improve because of their mean value which was lower than 2.4 were 'information and communication technology' (F20) 'research and development' (F22) within Technology Component and 'Cost of Management, Process, Training and Technology' (F24) under Cost component.

5.1.2 Readiness of Regulator Group

In this section, the analysis results which are a summary of regulator groups' readiness are shown in Table 5.2. The experts commented in their answers that People and Strategy Components under regulator group were 39% which meant those were in 'Secondary level' while Process and Technology components were between 40 and 60% that were in 'Tertiary level'.

Table 5.2: A Summary of Readiness Assessment Result for Regulator Group

		Factors	Component weight	Experts					Mean Score	Component mean score	Readiness of component (%)	Readiness of Regulator (%)
				E1	E2	E3	E4	E5				
Regulator	Process	F1	0.271	1	0	0	0	0	0.2	8.20	51%	47%
		F2		1	1	0	0	0	0.4			
		F3		4	4	4	4	4	4.0			
		F4		3	3	4	4	4	3.6			
	Tech:	F5	0.253	1	2	1	2	2	1.6	9.60	60%	
		F6		4	2	4	2	2	2.8			
		F7		4	2	2	3	2	2.6			
		F8		4	2	2	3	2	2.6			
	Strategy	F9	0.230	0	0	0	0	0	0.0	9.40	39%	
		F10		0	0	0	0	0	0.0			
		F11		3	1	3	3	1	2.2			
		F12		3	2	2	0	2	1.8			
		F13		4	3	3	3	2	3.0			
		F14		3	2	2	3	1	2.4			
	People	F15	0.246	3	2	3	2	2	2.4	8.20	41%	
		F16		3	2	3	2	2	2.4			
		F17		1	0	1	0	0	0.4			
		F18		3	2	2	3	2	2.4			
		F19		1	1	1	0	0	0.6			

And readiness percentage of regulator group was 47% in 'Tertiary level'. This means that the regulator group still needs to improve certain aspects under the components in order to achieve successful adoption of precast concrete method in construction

industry. The aspects that were required to improve were Government Policy (F1) and Proper Guidelines (F2) within Process Component, Research and Development (F5) within Technology Component, Tax Incentive (F9) and Developing a Road Map (F10) within Strategy Component and providing license for Experts and Profession (F17) and Skilled Workers (F19) in precast construction within People Component.

5.1.3 Readiness of Developer Group

This section gives information about the readiness of developer group for the adoption of precast concrete construction. Table 5.3 presents the readiness percentages of the developer and its associated components.

Table 5.3:A summary of Readiness Assessment Result for Developer Group

		Factors	Component weight	Experts					Mean Score	Component mean score	Readiness of component (%)	Readiness of Developer (%)
				E1	E2	E3	E4	E5				
Developer	Organization	F1	0.265	3	1	3	4	3	2.8	13.8	69.0%	70.0%
		F2		3	3	3	2	2	2.6			
		F3		3	2	3	4	3	3.0			
		F4		2	2	3	4	2	2.6			
		F5		3	2	3	4	2	2.8			
	Resource	F6	0.271	4	3	3	3	3	3.2	27.0	84.4%	
		F7		3	3	3	4	3	3.2			
		F8		3	2	3	3	2	2.6			
		F9		4	4	3	4	3	3.6			
		F10		4	4	4	4	3	3.8			
		F11		4	4	4	4	3	3.8			
		F12		3	3	4	4	3	3.4			
		F13		4	2	4	3	4	3.4			
	Market	F14	0.281	4	4	2	3	3	3.2	15.2	76.0%	
		F15		4	2	3	2	2	2.6			
		F16		4	3	2	2	2	2.6			
		F17		4	4	2	4	2	3.2			
		F18		4	4	3	4	3	3.6			
	External support	F19	0.184	4	0	2	0	0	1.2	6.6	41.3%	
		F20		0	0	0	0	0	0.0			
		F21		2	1	1	2	1	1.4			
		F22		4	4	4	4	4	4.0			

According to responses of the experts, Resource Component was strongest one which was at ‘Advance level’ with 84% while External Support Component was weakness one which was at ‘Tertiary level’ scoring 41%.

Furthermore, Organization and Market Components was at ‘Readiness level’ with 69% and 76% respectively. The overall readiness of the developer group was in ‘Readiness level’ scoring 70%. This concludes that the developer groups in Thailand

have adequate capability and are ready to adopt the precast concrete construction. The factors which needed to improve for developer were under External Support Component. Those were providing Government Policy (F19), Incentive and Promotion (F20) and Environmental Impact (F21).

5.1.4 Readiness of Customer Group

This section focuses on the evaluation of customer (house buyer) readiness for the application of precast concrete construction in housing industry. Table 5.4 presents the analysis result of the customer readiness for using precast concrete house.

Table 5.4: A summary of Readiness Assessment Result for Customer Group

		Factors	Component weight	Experts					Mean Score	Component mean score	Readiness of component (%)	Readiness of Customer (%)
				E1	E2	E3	E4	E5				
Customer	Awareness	F1	0.179	2	4	1	1	1	1.8	4.20	52.5%	50.3%
		F2		4	2	3	1	2	2.4			
	Knowledge	F3	0.120	1	2	0	2	2	1.4	5.00	41.7%	
		F4		0	3	1	1	1	1.2			
		F5		3	2	3	2	2	2.4			
	Liking	F6	0.169	2	1	3	3	1	2.0	5.60	46.7%	
		F7		2	2	3	0	1	1.6			
		F8		1	2	3	2	2	2.0			
	Preference	F9	0.160	1	2	3	1	1	1.6	5.00	41.7%	
		F10		2	2	3	2	1	2.0			
		F11		2	2	0	2	1	1.4			
	Conviction	F12	0.166	3	2	2	3	2	2.4	5.00	41.7%	
		F13		2	2	2	0	1	1.4			
		F14		1	1	1	2	1	1.2			
	Purchase	F15	0.206	4	2	4	4	3	3.4	8.40	70.0%	
		F16		4	1	3	3	2	2.6			
		F17		0	3	3	3	3	2.4			

After analyzing the responses of experts, all components of customer group were at ‘Tertiary level’ scoring between 40% and 60% except Purchase Components which was at ‘Readiness level’ with 70%.

The overall readiness of customer group regarding precast concrete house was at ‘Tertiary level’ scoring 50%. This means that only some customers prefer and interest in precast concrete house. And certain aspects were still needed to improve in order to achieve customer’s interest and preferences from many people. In conclusion, customer’s Awareness, Knowledge, Liking, Preference and Conviction components were required to improve for achieving readiness level.

5.1.5 Readiness of Construction Industry

This section gives information about the readiness of Thailand construction industry for the application of precast concrete construction. A summary of readiness assessment result for construction industry is presented in Table 5.5. And the weight value of stakeholders and its components calculated in Chapter 4 are presented in this table. Besides, readiness percentages of stakeholders and its components calculated in previous sections are also shown in the table. Then, the percentage of construction industry readiness can be calculated by summing the values that is obtained by multiplying stakeholder readiness percentages and its respective weight values. According to data in Table 5.5, the readiness percentage of the construction industry would be 61% (72x0.216 + 47x0.203 + 70x0.311 +50x0.270) and the results are plotted on the PCCRM Model diagram illustrated in Figure 5.1. In this figure, single line represents starting point of readiness level and double line means the current stakeholders’ readiness in the construction. According to answers of all experts, in Thailand construction industry, readiness of Contractor and Developer were at ‘Readiness level’ while Regulator and Customer were at ‘Tertiary level’. It concludes that generally, contractor and developer groups in Thailand have adequate capabilities and are ready to adopt the precast concrete construction while regulator group in Thailand still needs to improve and provide for certain aspects to be at readiness level, and just only some customers prefer and interest in precast concrete house.

However, the overall readiness of the construction industry is in ‘Readiness level’ scoring 61%. It demonstrates that generally, the construction industry has adequate capability and are ready to adopt the precast concrete construction. In order to achieve

better readiness for construction industry, Regulator and Customer group are required to improve their certain components.

Table 5.5: A Summary of Readiness Assessment Result for Construction Industry

Industry	Stakeholder	Components	Component's Weight	Component (%)	Readiness of Stakeholder (%)	Stakeholder's Weight	Readiness of Construction Industry (%)
Precast Concrete Construction	Contractor	Process	0.200	63%	72%	0.216	61%
		People	0.205	75%			
		Management	0.196	73%			
		Technology	0.198	74%			
		Cost	0.201	78%			
	Regulator	Process	0.271	51%	47%	0.203	
		Technology	0.253	60%			
		Strategy	0.230	39%			
		People	0.246	41%			
	Developer	Organization	0.265	69%	70%	0.311	
		Resource	0.271	84%			
		Market	0.281	76%			
		External support	0.184	41%			
	Customer	Awareness	0.179	53%	50%	0.270	
		Knowledge	0.120	42%			
		Liking	0.169	47%			
		Preference	0.159	42%			
		Conviction	0.166	42%			
		Purchase	0.206	70%			

5.1.6 Discussion

After assessing the responses from the five experts for case study, it could be seen that Regulator group was lowest readiness for the adoption of precast concrete technology among the stakeholders in Thailand and Customer group was second lowest readiness group being at ‘Tertiary level’. All components under Regulator and Customer groups

were required to improve except Purchase component of Customer group. On the other hand, Contractor and Developer groups were ready and capable to adopt the precast concrete construction being at 'Readiness level'.

Although overall maturity level of contractor group was in 'Readiness level', there were some factors under contractor group required to promote in order to be better readiness according to the survey result. Those were 'information and communication technology' (F20), 'Research & Development' (F22) under Technology component and 'Cost of Management, Process, Training and Technology' (F24) under Cost component.

According to Khoshnava, Rostami, Ismail, and Lamit (2014), lack of research and development and availability of limited technology were one of major barriers to adopt precast concrete construction. Some remarks of experts from interview section regarding R&D were "*R&D is important because the things that we discover from R&D are very useful and effective for products and customer.*" and " *Although assembling of precast concrete segments is not very complicated, R&D is still important in order to know how to make better connection, joint, construction sequence process and so on*". Application of information and communication technology (ICT) support along the process of precast concrete construction by providing accurate documents, less errors in production and assembly phases as well as more productivity (Ang & Kasim, 2013).

Musa et al. (2016) revealed that setting up budget for management, process, training and technology was vital in the adoption of IBS. Since changing in design of precast concrete construction increases addition construction time and cost, precast concrete construction needs comprehensive structure of process planning and controlling from beginning to terminating stage of the project (K. Kamar, Alshawi, & Hamid, 2009). Training and apprenticeship for assembler or coordinator is required to achieve socialized skills in the application of precast concrete construction (K. Kamar, Alshawi, & Hamid, 2009).

Regarding developer group, the overall readiness was at 'Readiness level' and most components of developer group were also at 'Readiness level' except External support component which was at 'Tertiary level'. External support refers to the

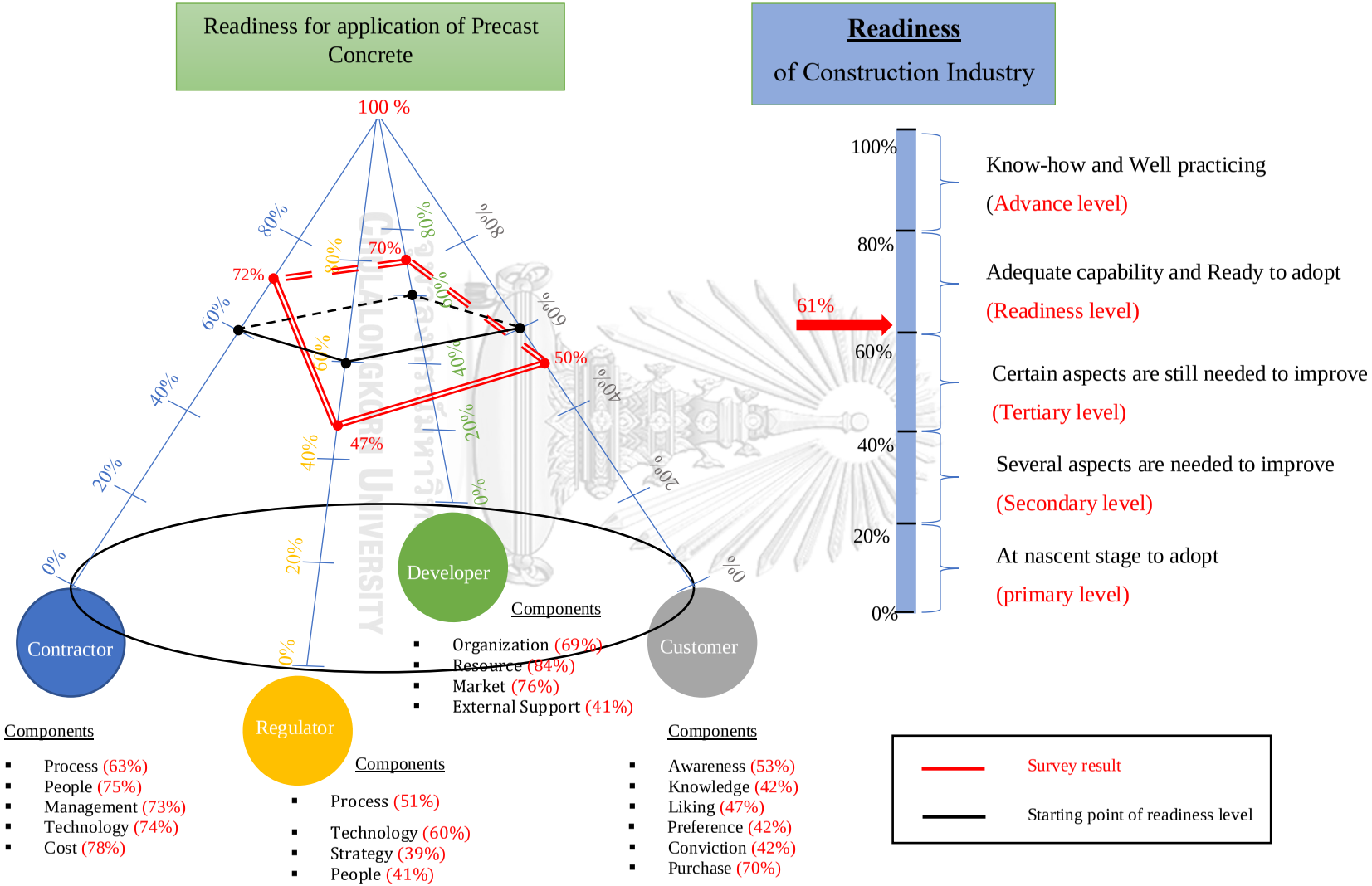

Figure 5.1: Readiness of Thailand Construction Industry

supports which the government provides to the developer. It is one of the most significant components which influence readiness of the housing developers to adopt innovative system in Malaysia. Moreover, strong external support and high market readiness make better readiness of housing developer to adopt innovative system (Yusof & Mohd Shafiei, 2011). Therefore, the government should provide the developers to obtain higher readiness level. Nevertheless, overall readiness of developer group was at 'Readiness level'.

This concluded that the developer group in Thailand had adequate capability and was ready to adopt the precast concrete construction. Currently, most of housing developers in Thailand are widely applying precast concrete construction in their projects. One of the experts from interview section revealed that "*In Thailand, normally, using precast concrete construction method is more expensive than normal traditional construction method. But most of the developers want to use precast concrete construction in their project due to the labor shortage*".

About the government group, the PCCRM model showed that the overall readiness was at 'Tertiary level'. This meant that the regulator group still needed to improve and support for certain aspects within components to achieve the 'Readiness level'. Regarding Process components of the government group, Government policy (F1) and Proper guidelines (F2) were required to support. Hashemi (2009) revealed that government policies are crucial because it can greatly influence the construction industry of a country. For instance, Malaysia government has set up a policy to use IBS components not less than 70% in all government projects (Mohammad et al., 2014). According to Mohammad et al. (2014), lack of proper guidelines for the application of IBS was a cause of distress to the stakeholders.

For Technology component under government group, Research and Development (F5) needed to improve in order to reach better stage of readiness. Lack of research and development services discourages the development and innovation of off-site construction (OSC). The government investment in research and development (R&D) will improve the maturity level of the application of OSC (Mao et al., 2013).

Concerning Strategy and People component of the government group, the overall readiness was lower than 'Readiness level'. All the factors under these components

were weak and required to be improved. Therefore, the government should set up some programs and strategy in order to improve Strategy and People components. Rossi (2014) revealed that government program such as tax incentives, promotions, road maps and directives make the use of precast concrete increase in national industry. Moreover, the government is the one who has authority and ability to establish the fundamental institutional enabler to achieve better business situation and to build skilled level industry by providing incentive, taxation and other programs. For instance, Malaysia government developed the IBS Roadmap through the Cabinet of Ministers for construction sector (K. Kamar, Alshawi, & Hamid, 2009). Moreover, Malaysia government creates many programs in order to achieve successful implementation of IBS. Incentive is provided for the contractor in the form of tax exemption of the construction (0.125% of the whole project cost) that used IBS at least 50%. Tax incentive is also given in that situation when moulds that is used for precast concrete component production are purchased (Rossi, 2014). In addition, HAW (2009) expressed that offering attractiveness for achieving possible margins and incentives in increase of government projects using IBS is one of the critical factors.

Hashemi (2009) stated that responsibility of the government was to create some specialist organizations, more seminars and educational courses to introduce and promote precast concrete technology in construction sector. Moreover, he said that engineer and labors should have certificates or licenses which were offered by the government in order to become certified skilled labors and experts in precast concrete. Furthermore, the government should provide training and education program to construction persons to achieve knowledge, awareness and continuous learning and improvement in precast concrete technology.

Result from the PCCRM model indicated that the overall readiness of customer group was at ‘Tertiary level’. This concludes that only some home buyers interest in and prefer to precast concrete house. In Thailand, the reason of not being at “Readiness level” is that some of the customers have less knowledge about the advantages and hinderance of precast concrete house. In addition, some customers, especially high-income groups do not like to buy or build load bearing wall precast concrete houses.

One of the experts from interview section said, "*In Thailand, sometime customers have no chance to choose traditional house since most of house developers adopt precast concrete technology to build their housing projects for low- and medium-income group*". This implies that sometimes, low- and medium-income group customers just buy the houses that home developers offer no matter whether they have knowledge and awareness, or they do not know about precast concrete house. To reach the 'Readiness level', components under customer group which are Awareness, Knowledge, Liking, Prefer and Conviction needed to be improved by conducting advertisement through television, social media and billboards.

In summary, according to analysis results through PPCRM model which were shown in Table 5.5 and in Figure 5.1, the whole construction industry readiness for the application of precast concrete construction was at 'Readiness level'. In Thailand, Contractor and Developer group were at 'Readiness level' while Regulator and Customer group were at 'Tertiary level'. It can be noticed that Contractor and Developer drive mainly precast concrete construction in Thailand construction industry. One of the experts from interview section answered that "*In Thailand, Contractor and Developer group are major drivers for the implementation of precast concrete construction. The government does not support anything to change to use precast concrete construction*". Therefore, among the stakeholders in Thailand construction industry, Government group and Customer group can be improved for achieving higher readiness level.

The PCCRM model has been applied on real life construction industry in to assess the readiness for the application of precast concrete construction. And the case study demonstrated that the PCCRM model was able to assess the readiness of precast concrete application for construction industry. Therefore, it can be concluded that the PCCRM is reliable to apply for assessing the readiness of Myanmar construction industry. The next sub section presents about the readiness assessment of precast concrete application in Myanmar.

5.2 Readiness Assessment for the Application of Precast Concrete Construction in Myanmar

Regarding the assessment of Myanmar construction industry readiness for the adoption of precast concrete construction, a case study was conducted. In this case study, there were four groups of respondents which are major stakeholders in precast concrete construction for data collection. The stakeholders were Regulator (government), Developer, Contractor and Customer (house buyer). Totally, 43 sample numbers were used. Fifteen Contractor companies, ten Developer companies and three regulator organizations were randomly selected for the purpose of case study and face to face interviews were also conducted for qualitative verification. Then, they were asked about their organization activities and situation regarding the readiness for the application of precast concrete construction. These respondents are from middle management or upper management who are qualified to provide the situation and information of their companies or organizations.

For customer groups, 15 house buyers were randomly chosen from real estate agencies listed in Yangon. Telephone interviews were then carried out. Figure 5.2 depicts distribution of respondents. The readiness percentage of Myanmar construction industry and stakeholders were obtained from the result of the case study. In addition, the result implies the components and criteria of stakeholders required to improve to reach the readiness level.

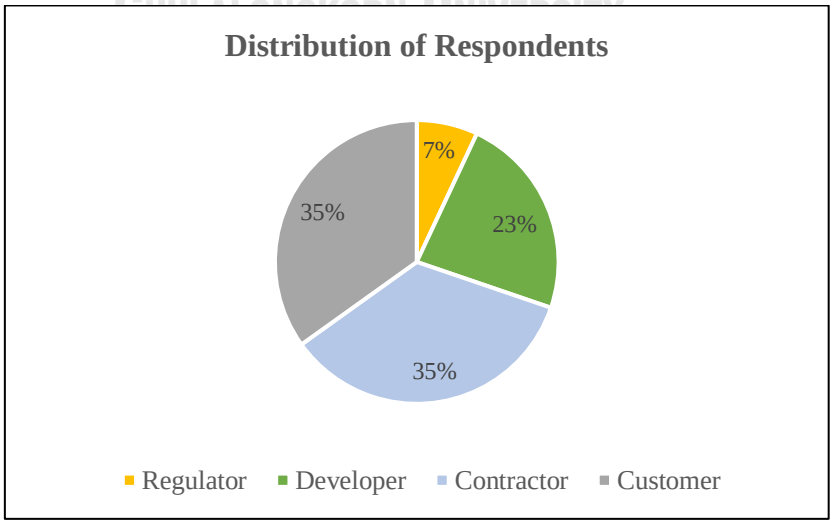

Figure 5.2: Distribution of Respondents Based on Stakeholder Group

The method and procedure of percentage calculation for construction industry and stakeholders in order to use in PCCRM Model are similar as mentioned in Section 5.1.1. The maturity levels of Myanmar construction industry and stakeholder groups for the adoption of precast concrete construction were shown in following sections.

5.2.1 Readiness of Contractor Group

Fifteen Contractor companies were randomly selected in order to assess the readiness of Myanmar contractor group for the adoption of precast concrete construction. A summary of readiness assessment result is arranged in tabular form and shown in Table 5.6. Besides, this table presents the readiness percentage of all components under the contractor group.

Table 5.6: A Summary of Readiness Assessment Result for Contractor Group

Group	Component	Factors	Component weight	Mean Score	Component mean score	Readiness of component (%)	Readiness of Contractor (%)
Contractor	Process	F1	0.200	2.87	14.267	59%	53%
		F2		2.67			
		F3		2.87			
		F4		2.47			
		F5		0.87			
		F6		2.53			
	People	F7	0.205	2.27	8.867	44%	
		F8		0.80			
		F9		1.60			
		F10		1.80			
		F11		2.40			
	Management	F12	0.196	2.87	12.933	54%	
		F13		0.93			
		F14		2.67			
		F15		2.13			
		F16		2.20			
		F17		2.13			
	Technology	F18	0.198	1.87	8.267	41%	
		F19		2.47			
		F20		0.93			
		F21		2.27			
		F22		0.73			
	Cost	F23	0.201	3.07	10.800	68%	
		F24		1.47			
		F25		3.00			
		F26		3.27			

The percentage of each component was calculated after analyzing the questionnaire responses from the selected companies. According to assessment result, all components were at ‘Tertiary level’ scoring between 40 % and 60% except Cost component which was at ‘Readiness level’ with 68%. The overall maturity percentage of contractor group was 53% at ‘Tertiary level’. This means that the contractor groups in Myanmar are possible to be capable for adoption of precast concrete construction, but the team will be struggled and face difficult in the adoption. They were still needed to improve certain aspects within components for achieving the successful adoption of precast concrete construction. The factors needed to be improved were Proper guideline ‘F5’ under Process component and almost all factors under remaining components of contractor group which mean score is lower than 2.4.

5.2.2 Readiness of Regulator Group

In order to assess the readiness of regulator (government) group for the adoption of precast concrete construction, the researcher selected three governmental organizations which are ‘Ministry of Construction (Housing Development)’, ‘Ministry of Construction (Urban and Regional Development)’ and ‘Yangon City Development (YCDC). All respondents from these three organizations are from middle management level. A summary of readiness assessment result for regulator group is presented in Table 5.7.

The percentage of each component was calculated after analyzing the answers of the questionnaires from each organization. According to assessment result, percentage of Strategy component was lowest when compared with other components under regulator group and it was at ‘Primary level’ with 18% while Process level was at ‘Tertiary level’ with 48%. Technology and People components under regulator group were at ‘Secondary level’ scoring between 20% to 40%. The overall readiness of regulator group is at ‘Secondary level’ with 34%. This concludes that regulator needs some improvement and provides several supports to the industry to be successful adoption of precast concrete in construction industry. All factors under Strategy and People components, Government Policy (F1) and Proper Guidelines (F2) within Process components and Research and Development (F5) and Design Standardization and Codes within Technology components were required more attentions.

Table 5.7: A Summary of Readiness Assessment Result for Regulator Group

Group	Component	Factors	Component weight	Mean Score	Component mean score	Readiness of component (%)	Readiness of Regulator (%)
Regulator	Process	F1	0.271	0.67	7.667	48%	34%
		F2		1.00			
		F3		3.67			
		F4		2.33			
	Technology	F5	0.253	0.67	6.000	38%	
		F6		0.00			
		F7		2.67			
		F8		2.67			
	Strategy	F9	0.230	0.00	4.333	18%	
		F10		0.00			
		F11		1.33			
		F12		1.33			
		F13		1.67			
		F14		0.00			
	People	F15	0.246	2.00	6.000	30%	
		F16		2.00			
		F17		0.00			
		F18		2.00			
		F19		0.00			

5.2.3 Readiness of Developer Group

This section gives information about result of case study which is readiness of developer group in Myanmar construction industry for the adoption of precast concrete construction. Ten developer companies were randomly chosen and face to face interview were conducted in order to obtain complete responses for questionnaire. The readiness analysis is presented in Table 5.8 that gives information about maturity percentage of all components of developer group. The percentage of each component under developer group was calculated based on the responses of questionnaire from each company. According to assessment result of the responses, the readiness of the Organization and Resource components of developer group were at ‘Tertiary level’ scoring 49% and 43% respectively. And the readiness of Market and External Support components were at ‘Secondary level’ with 29% and 22% respectively.

The overall readiness result of developer group in Myanmar construction industry for adoption of precast concrete construction was at 'Secondary level' achieving 37%. This means that there are many barriers that are needed to solve by improving several aspects of components for successful adoption of precast concrete construction for developer group in Myanmar. Expect Firm's Encouragement (F1), Risk-averse Culture (F2), Continuous Improvement & Learning (F3), Machineries and Equipment (F10) and Government Regulation (F22), the remaining factors of developer groups were required improvement.

Table 5.8: A Summary of Readiness Assessment Result for Developer Group

Group	Component	Factors	Component weight	Mean Score	Component mean score	Readiness of component (%)	Readiness of Developer (%)
Developer	Organization	F1	0.265	2.40	9.700	49%	37%
		F2		2.90			
		F3		2.40			
		F4		0.50			
		F5		1.50			
	Resource	F6	0.271	1.40	13.900	43%	
		F7		1.30			
		F8		1.70			
		F9		1.90			
		F10		2.50			
		F11		1.60			
		F12		1.50			
		F13		2.00			
	Market	F14	0.281	1.20	5.800	29%	
		F15		1.20			
		F16		1.20			
		F17		0.10			
		F18		2.10			
	External support	F19	0.184	0.20	3.500	22%	
		F20		0.00			
		F21		0.20			
		F22		3.10			

5.2.4 Readiness of Customer Group

In this case study, 15 customers (house buyer) were randomly selected and telephone interview were conducted to obtain perfect responses of questionnaire and to avoid misunderstandings about questionnaire. Based on respondents' answers, an assessment readiness result of customer group in Myanmar is tabulated and shown in Table 5.9, presenting percentage of all components under customer group.

Table 5.9: A Summary of Readiness Assessment Result for Customer Group

Group	Component	Factor	Component weight	Mean Score	Component mean score	Readiness of component (%)	Readiness of Developer (%)
Customer	Awareness	F1	0.179	1.000	1.667	21%	26%
		F2		0.667			
	Knowledge	F3	0.120	1.400	4.067	34%	
		F4		1.133			
		F5		1.533			
	Liking	F6	0.169	1.200	3.067	26%	
		F7		0.933			
		F8		0.933			
	Preference	F9	0.160	1.067	3.000	25%	
		F10		1.000			
		F11		0.933			
	Conviction	F12	0.166	1.200	2.733	23%	
		F13		0.733			
		F14		0.800			
	Purchase	F15	0.206	1.933	3.400	28%	
		F16		1.333			
		F17		0.133			

After analyzing the responses of the customers, the assessment result showed that all components of customer group were at ‘Secondary level’ scoring between 20 to 40%. The overall readiness of customer group in Myanmar for adoption of precast concrete construction is at ‘Secondary level’ achieving 26%. This means that several aspects are required to be promoted for attaining customer’s interest and preference in houses built by precast concrete construction. All factors under each component of customer group need to improve for achieving the successful adoption of precast concrete in Myanmar construction industry.

5.2.5 Readiness of Construction Industry

This section gives information about the overall readiness assessment result of Myanmar construction industry. Based on the questionnaire responses from respondents, the maturity percentage of stakeholders and construction industry were calculated by summing the results that is obtained by multiplying stakeholder percentages and its respective weight values.

The overall readiness assessment results of Myanmar construction and stakeholders are shown in Table 5.10 and are plotted in PCCRM Model diagram illustrated in Figure 5.2. According to survey result of the case study, maturity of Myanmar stakeholders in construction industry were at ‘Secondary level’ scoring the percentage between 20 to 40%, except maturity of Contractor group which was in ‘Tertiary level’ with 53%.

The overall readiness of Myanmar construction industry was in ‘Secondary level’ scoring 37%. This concludes that all stakeholders require to improve several aspects to reach readiness level such as providing incentive and promotion for precast users by government, advertising to house buyers about precast concrete house, supporting training and education and promoting in continuous learning and development and etc.

Table 5.10: A Summary of Readiness Assessment Result for Construction Industry

Industry	Stakeholder	Components	Component's Weight	Component (%)	Readiness of Stakeholder (%)	Stakeholder's Weight	Readiness of Construction Industry (%)
Precast Concrete Construction	Contractor	Process	0.200	59%	53%	0.204	37%
		Management	0.205	44%			
		People	0.196	54%			
		Technology	0.198	41%			
		Cost	0.201	68%			
	Regulator	Process	0.271	48%	34%	0.185	
		Technology	0.253	38%			
		Strategy	0.230	18%			
		People	0.246	30%			
	Developer	Organization	0.265	49%	37%	0.333	
		Resource	0.271	43%			
		External Support	0.281	29%			
		Market	0.184	22%			
	Customer	Awareness	0.179	21%	26%	0.278	
		Knowledge	0.120	34%			
		Liking	0.169	26%			
		Preference	0.159	25%			
		Conviction	0.166	23%			
		Purchase	0.206	28%			

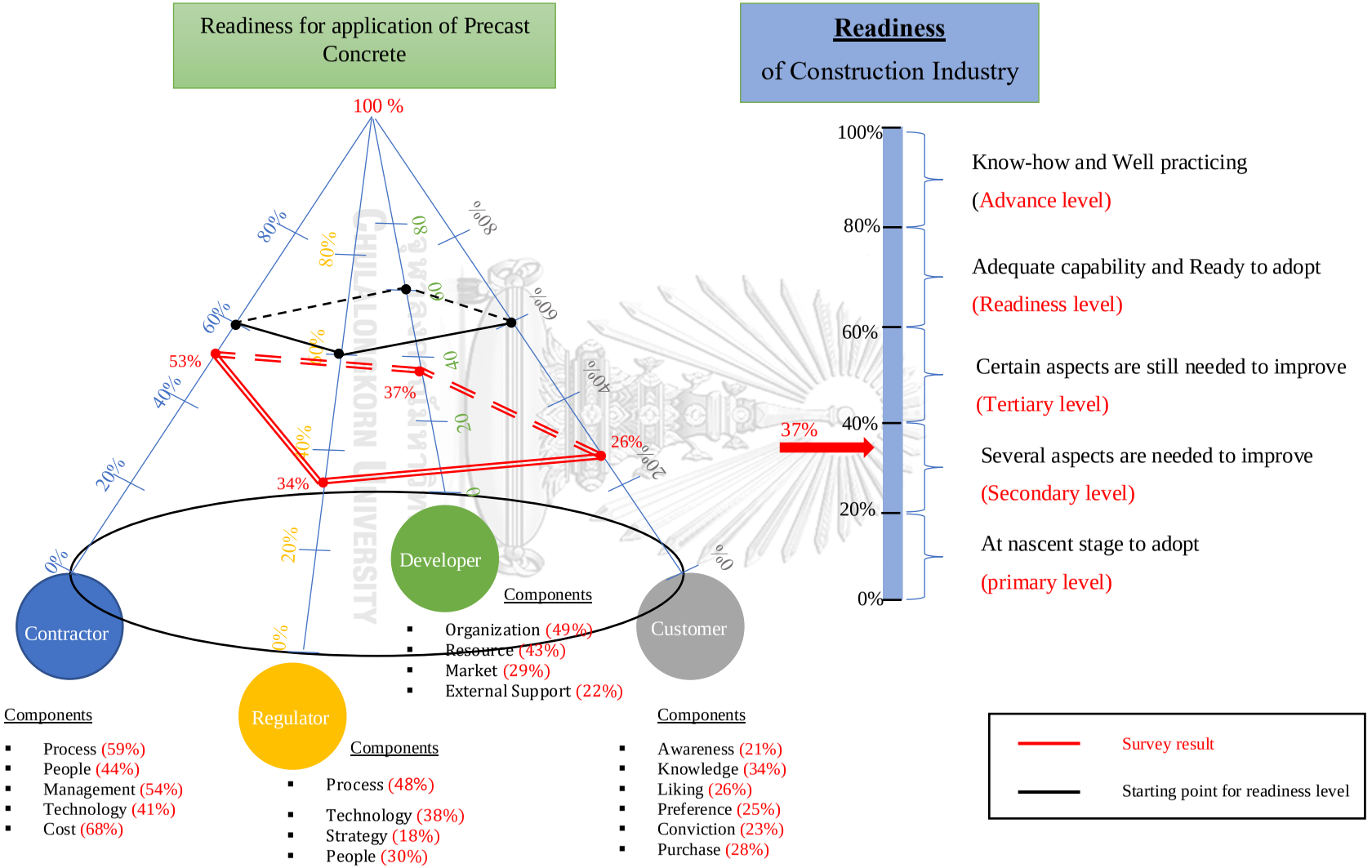

Figure 5.3: Readiness of Myanmar Construction Industry

5.2.6 Discussion

After analyzing the responses from questionnaire survey to evaluate the readiness of construction stakeholders and construction industry in Myanmar, it could be seen that the readiness of Myanmar construction industry was at 'Secondary level'. Among the stakeholders, the readiness percentage of contractor group was highest being at 'Tertiary level' and customer group was lowest achieving 'Secondary level' while the readiness percentage of regulator and developer groups was 34% and 37% being at 'Secondary level'. It means that readiness of all stakeholders and construction industry have not achieved 'Readiness level' yet and there are several weakness, barriers and difficulties for the adoption of precast concrete construction in Myanmar. Moreover, there are very few numbers of houses which are currently applied precast concrete load bearing wall construction in Myanmar.

Regarding contractor group, proper guideline for precast concrete construction under process component is one of the factors that need to be improved. Since precast concrete construction is not popular in Myanmar, most of contractor companies do not interest in whether there is proper guideline for precast concrete construction and the government also should support the guideline for the application of precast concrete construction. Mohammad et al. (2014) revealed that lack of guidelines was a cause of distress to stakeholders for the implementation of precast concrete construction.

Concerning people component of contractor group, according to responses of survey questionnaire, most of contractor companies had less knowledge and awareness in precast concrete construction. Tamrin, Nawi, and Nifa (2016) mentioned that lack of knowledge and awareness was one of major problems in readiness issue. Lack of knowledge and awareness among workforces including engineers, designers and workers occur delaying the project and requiring the extra time to implement the project. Knowledge and awareness of precast concrete are important for all stakeholders involved in adoption of precast concrete and it will help to be better overall performance of the project (Mushtaq Ahmad, 2017).

Adoption of precast concrete offers many advantages for construction stakeholders. However, there are some workforces who have negative perception on that system

because it was assumed that precast concrete system could make shortage of job opportunities in construction industry. One of the respondents revealed that, "*Although we as a main contractor would like to adopt precast concrete system, some of our sub-contractors who supply labor forces don't want to accept because they are afraid of losing their people jobs*".

Another major issue that is requires to be considered for adoption of precast concrete construction is availability of skill labors for precast concrete panel installation at the site as well as experienced and technical capable workforces. Myanmar lacks skilled labors not only for general construction work but also for precast concrete construction. One of respondents answered that "*at this moment, it is difficult to find skilled labors and experienced work forces for precast concrete construction in local construction market. But there might be some migrant workers who have experience about precast from oversea countries*". Therefore, availability of skilled labors becomes another important issue in Myanmar when precast concrete construction is adopted. In order to solve that issue, providing training will become vital. Unfortunately, in Myanmar, practices of providing training is rare, especially in small construction companies. Lack of readiness in training influences the readiness of industrialized building system (IBS) implementation. In order to avoid lack of readiness, providing training to the organizations about how to handle IBS project and how to manage the organizations that adopt IBS can be conducted. (Tamrin et al., 2016).

Management component is an important issue for the application of precast concrete construction since management of traditional construction and precast concrete construction are not similar in serval processes and traditional management may not be the best way to approach precast concrete construction (Bagenholm, Yates, & McAllister, 2001). Precast concrete construction is required to be planned and carried out from the beginning of design stage together with precast manufacturer, designer and other parties in order to attain the business target in precast concrete construction.

In Myanmar, since there are very few precast concrete projects and the use of precast concrete technology in housing industry is not popular yet, most of contractor companies have less experience and confidence in management of precast concrete

construction. As a consequence, the contractors companies have no strategic approach for precast concrete business and know a little about management of supply chain and procurement in precast concrete construction. One respondent mentioned that, "*It is possible to handle logistic for precast concrete construction since it is not so complicated, but they are not sure for procurement and supply chain management for precast concrete project*". Moreover, most of contractor companies are absent from conducting risk management for their projects, except big companies in the construction industry. Performing risk management is a crucial factor in precast concrete practices because it provides contingency measures to deal with unexpected cases such as delays, accidences and disruption at every stage of the implementation of precast concrete construction (Bendi, 2017).

Technology is one of the important aspects that is required to consider for production, lifting, assembling, execution and quality control when precast concrete construction is adopted. Khoshnava et al. (2014) mentioned that lack of research and development (R&D), the use of ICT and availability of limited technology were discouragement of IBS adoption. In Myanmar, lack of R&D for precast concrete technology and lack of the use of ICT such as BIM technology in construction companies are currently found. Moreover, availability of precast concrete factories and facilities are still limited, especially for precast concrete load bearing wall although there are some precast concrete manufacture companies. In addition, the characteristics of precast concrete construction rely on heavy machineries and equipment. In Myanmar, despite machineries and equipment for lifting and assembling are available sufficiently, rental fees for those are still expensive. One of the respondents revealed that, "*In Myanmar, we can find and hire the cranes easily for lifting precast concrete panels. But the rental fees are expensive and higher three times than the price in Thailand*".

Cost issue is almost the most important one required to consider when adopting precast concrete construction. The organization must have knowledge about various possible cost of precast concrete application and sufficient fund in order to execute precast concrete construction. According to responses of questionnaire, most of contractor companies in Myanmar understand and have knowledge about the cost of precast concrete construction. However, considering the budget for cost of

management, training, process and technology is not normal practices. Cost can be classified into two major categories which are immediate costs and life costs. Immediate costs mean all the costs used in building process while life costs are operating and maintenance costs of the building in long term. Both of them should be taken into account when adopting the precast concrete construction (Hashemi, 2009). However, most of the people in Myanmar consider only immediate costs when conducting cost comparison between application of precast concrete and traditional construction methods. As a result, most of the people think that application of precast concrete construction is more expensive than traditional method.

In summary, according to responses of questionnaire, readiness of Myanmar contractor group for the adoption of precast concrete was at 'Tertiary level'. It means the contractor groups are possible to be capable for adoption of precast concrete construction, but certain aspects are still required for improvement to reach the readiness level.

About Developer group in Myanmar, weakness criterions that make low readiness of organization component are lack of knowledge and awareness about precast concrete technology and research and development. Not only lack of knowledge and awareness but also lack of reliability in precast technology among developers is one of the reasons ignoring precast concrete construction in housing industry (Hashemi, 2009). In addition, developer group has many barriers regarding resources for adoption of precast concrete construction in housing. Those are the limited availability of experts and professions in precast concrete technology, skill labors for erecting precast concrete segments, contractors specialized in precast concrete construction and precast concrete manufactures. Regarding factory cost, although most of developer companies are capable and have financial ability, they have no plan to invest when they adopt precast concrete construction in their housing projects.

With regard to the market, although housing demand in the market seems high, the buying power of low-and medium-income groups is low. It means that a lot of people are acquiring houses and apartments, but they are not capable to purchase because of their low income. Moreover, there are lack of mass building projects in private sector rather than those in the government projects. One of respondents from developer

group mentioned that "*The reason for not applying precast concrete construction in housing industry is the higher cost compared with traditional method. He knows that adoption of the method can accelerate the construction speed and it might be economical for mass building projects. However, at this moment, there are only small developers in Myanmar construction industry when compare with developed countries*". Furthermore, another respondent from developer group revealed that, "*The government should revise current land policy in order to see mass building developments in private sector because in Myanmar, the government defines many types of land for many purposes such as Freehold land, Farmland, Agricultural land and so on. For example, in some countries, if the people own a land, any kind of building can be constructed in their land. But in Myanmar, we need to check what type of land first and most of the lands near city parameters are not the land for residential building*."

Another issue is about customer perception and willingness to use precast concrete method. Hashemi (2009) said that some of the UK people had negative perception in prefabrication systems because of the memories of previous projects' bad performances. As the survey result in Myanmar, customer perception and willingness in precast concrete are ambivalent since the customers have lack of knowledge about precast concrete method. However, when the Myanmar society is compared to the UK, Myanmar people have better perception in precast concrete method because there was no bad news of precast concrete project yet in Myanmar. Concerning external support component, in Myanmar, according to survey result, there is no government policy, incentive and promotion in order to attract the stakeholder for adoption of precast concrete construction in housing industry. Moreover, there is no encouragement from government yet for stakeholders to reduce environmental impact by using alternative methods in construction industry. After all, as the result of PCCRM model analysis, readiness of developer group was at 'Secondary level'. It concludes that developer group in Myanmar are not ready yet and there are several aspects required to be promoted and supported for achieving readiness level.

About regulator group, it is the one who has authority and ability to improve and create the fundamental institutional enablers, business cases and industrial skill levels

through incentive and promotion program, tax collection and other programs (Du Plessis, 2007). Government policies are very crucial to the country and can greatly affect the construction industry. Unfortunately, as the survey result, there is no government policy yet for private construction sector about the adoption of precast concrete construction in Myanmar. However, government regulation allows to use precast concrete method in housing projects in Myanmar. Most of the Myanmar's government design regulations for construction industry are almost references to UK and American's standards. Therefore, one of the respondents from the regulator group answered that, "*If design and regulation of proposed precast concrete projects comply with those regulations, the government allows to use it but so far, specific local regulation for precast concrete is not defined yet*". Regarding the guidelines for the application of precast concrete construction, the respondents said that "*the government had not published yet for private projects. Yet, the government took references to Singapore guidelines for government public precast construction projects*". Transportation and logistics issues should also be considered when adopting precast concrete construction as Myanmar has not much efficient infrastructure and transportation system. There might be potential problems such as transportation permits, overhead obstruction, access road and bridge capacities to the construction site depending on the location when precast concrete method are applied in downtown areas of Myanmar.

Regarding technology components of regulator group, although the regulator group has knowledge in precast factory & facilities and machineries & equipment for precast concrete, they have less focus on research and development (R&D). Lack of R&D institutes and service is one of the barriers for adoption of precast concrete construction in Myanmar and, in consequences, stakeholders are reluctant to apply and innovate the precast concrete technology. Therefore, investment of the government in R&D greatly influence the readiness of precast concrete construction application (Mao et al., 2013). Another issue is that based on survey result, there is no design standardization and codes which are published by the government yet for precast concrete construction. However, the government allows when stakeholders follow ACI or BS codes and standardization for precast concrete construction.

Hashemi (2009) revealed that the government should encourage standardization of precast components to promote the use of precast concrete in construction.

Programs from the government strategy such as incentives, development of the roadmap, promotions, directives and exhibitions helps to accelerate application of precast concrete (Rossi, 2014). However, it seems that the government has not implemented incentives, roadmap, promotions and exhibitions for precast concrete construction in Myanmar yet. But one of respondents from government group said that, "*The government developed roadmap internally for the adoption of precast concrete in government housing project. Unfortunately, the roadmap was not achieved as target plan while it was implementing and now it is pending because of various reasons*". Regard with increasement of government projects using precast concrete, there have recently been some projects in which the government provides lands to some developers with special land price in order to develop the housing projects by using precast concrete system. However, some of the projects were not completely successful and not accomplished as the plan. Application of precast concrete construction can make construction industry more sustainability and better environment as it can reduce energy and materials which are wasted at the site (Hashemi, 2009). Therefore, adoption of precast concrete construction will offer advantages for the environment. However, in Myanmar, there is no government encouragement for stakeholders to reduce environmental impact by using alternative methods in construction industry.

Concerning people component of regulator group, most of government staffs have knowledge and awareness about precast concrete and the organization supports and encourage the staffs to be continuous learning and improvement. Moreover, training and education programs are provided usually for the staffs. However, there are still lack of programs that offer licenses or certificates by the government in order to become certified skilled labors and experts in precast concrete construction. Hashemi (2009) mentioned that responsibility of the government is to create some specialist organization, more seminars and educational courses regarding precast concrete technology in order to introduce and promote in construction sector.

All in all, the readiness of regulator groups in Myanmar for the application of precast concrete construction is at ‘Secondary level’. This indicates that there are several activities required to support and several aspects needed to improve by government group to reach the readiness level for the adoption.

regulator group needs to improve and provide for several aspects (within components) to be successful adoption of precast concrete in the construction industry.

The readiness percentage of customer group in using precast concrete house was lowest among stakeholders in Myanmar. And readiness of all components which were awareness, knowledge, liking, preference, conviction and purchase of customer group were very low at ‘Secondary level’. The main reasons of being low readiness of customer group in Myanmar are lack of promotion and advertisement about precast concrete, a few precast concrete projects, unpopularity of using precast concrete methods and lack of government support for adoption of precast concrete construction.

In order to improve the readiness of customer group, some activities can be carried out. Berger and Wallingford (1997) revealed that “Awareness” can be built with simple ads, but those should be memorable ads. These ads will serve to obtain awareness of customers that the product or method exists and is possible substitute in existing product or method. For ads, the vehicle which are TV, print or mail can be applied. Regarding knowledge, after awareness has been built adequately, the marketer can start to expand the knowledge about the product or method. The appropriate strategy is focusing on prospective group or customer by providing variety of information with detail about the product or method. Liking, preference and conviction which drive to purchase appear once the customer has awareness and knowledge. To sum up, readiness of customer group for the use of precast concrete house was very low in Myanmar. It should be improved by developing some advertising and promotion strategies to achieve successful adoption of precast concrete in Myanmar construction industry.

In conclusion, readiness of the whole Myanmar construction industry was very low at ‘Secondary level’. It implies that all stakeholder groups and their components are still

needed to be upgraded for being the construction industry which are ready to use precast concrete.

5.3 Conclusion

This Chapter has presented construction industry readiness of the application of precast concrete construction in Thailand and Myanmar based on assessment result of case studies through PCCRM model. Moreover, this study has mentioned about methodology for the assessment, readiness of each stakeholder in construction industry and weaknesses of each stakeholder required to improve.

According to the case studies, the overall readiness result of Thailand construction industry for the application of precast concrete construction showed that the industry was capable and ready to adopt while the overall readiness result of Myanmar construction industry presents that the industry was not ready yet to adopt. Regarding stakeholders in the industry, regulator and customer group in Thailand are still needed to improve in order to reach readiness level while all stakeholders in Myanmar construction industry are required to improve in several areas to be ready for the adoption of precast concrete construction.

This study presented that the PCCRM model has been applied on real life construction industry and the two case studies demonstrated the method to assess the readiness of precast construction industry. The next chapter will present the conclusion of the research.

CHAPTER 6
RESEARCH CONCLUSION

The objective of this chapter is to summarize the research results which are the new readiness model development for adoption of precast concrete construction and also the measurements of readiness of Thailand and Myanmar construction industries regarding the application of precast concrete. And this chapter mentions the summary of the research, research aim, objectives, contribution and limitations. Moreover, recommendations for future works are also presented.

6.1 Main Research Findings

The aim of the research was to develop a new readiness model that can assess the readiness of the construction industry including major stakeholders for the application precast concrete construction in housing projects. The aim of the research has been accomplished by fulfilling the research objectives that were mentioned in Chapter 1:

1. To investigate advantages, hindrances and the factors that influence the application of precast concrete construction through literature review for the development of the model

This study reviewed several previous researches concerning precast concrete and presented various advantages, hindrances and the factors that influence the application of precast concrete construction as documented in Chapter 2. Hence, 84 factors were selected from the previous research to use in the development of the readiness model through document analysis method and semi-structure interview with experts.

2. To conceptualize a new readiness model to assess the application of precast concrete construction by exploring existing readiness assessment tools, models and framework from various industries

The readiness models, tools and frameworks that are available currently in the construction and other industries were intensively reviewed. Comparison of the models was performed to identify the applicable models and frameworks for our study area. Then, they and the data from real world practices were combined and modified

to introduce the conceptualized readiness assessment model. Finally, the model was validated by conducting semi-structure interview with five experts and a pilot test.

3. To assess the maturity level of construction stakeholders and industry for the application of precast concrete in housing projects

Case studies were conducted to assess the readiness of the construction industry including contractor, developer, regulator and customer in Thailand and Myanmar. According to analysis result of responses from questionnaire, the maturity level of Thailand construction industry for the application of precast concrete construction was at 'Readiness level' while the maturity level of Myanmar construction industry was at 'Secondary level'. Moreover, the maturity level of construction stakeholders in Thailand and Myanmar for the adoption of precast concrete construction were presented.

Other findings from this research were presented as follows:

- Based on the intensive literature review regarding precast concrete, it could be concluded that adoption of precast concrete had the potential advantages such as easier and quicker construction for the building, lower overall cost of the project, better quality and durability of the materials, less buidling materials wastage, better sustainability and occupational health and safety;
- Evaluation of the readiness or maturity of the adoption of the precast concrete system is essential to improve the weak points of the organization or construction industry before the adoption of the precast concrete system;
- In order to assess the readiness of construction industry for the application of precast concrete construction, a new readiness model (PCCRM) was required because existing models were not covered to assess the readiness of the construction industry.
- According to assessment result, Thailand construction industry was ready and capable to adopt the precast concrete construction. Developer and contractor groups were major drivers to adopt the precast concrete construction in housing industry among the stakeholders in Thailand.

- For Myanmar construction industry, the overall readiness was at ‘Secondary level’ which indicated that the industry was required to improve in several aspects for obtaining successful adoption in housing projects.

6.2 Research Contribution

The main contribution of the research is the development of precast concrete construction readiness model (PCCRM) for adoption of precast concrete method in construction industry. Moreover, application of this model will facilitate as a guideline for stakeholders which are presently applying or have plan to apply the precast concrete technology for reaching the successful adoption of the technology and business target. In addition, the readiness assessment results of case studies provide knowledge on the current situation of precast concrete application, the drivers and barriers for adoption of precast concrete construction in Thailand and Myanmar construction industries.

6.3 Advantages of PCCRM Model

The potential benefits of the PCCRM model when compared with other models are described below:

- The PCCRM model can be applied not only for the construction industry but also for self-assessment on four major stakeholders: Contractor, Developer, Regulator and Customer in order to know the readiness of the adoption of precast concrete construction
- Application of PCCRM model provides strengths and weaknesses of the construction stakeholders (organizations) and industry concerning the adoption of precast concrete construction.
- This model and its associated factors are specifically tailored to meet the needs of the readiness for application of precast concrete construction.
- When another construction method or product is adopted, this model can also be used by revising the factors to the new context. (e.g. assessment of the use of post-tension method or 3D printing construction method)

- Application of the PCCRM model for the readiness assessment of construction stakeholders (organization) and industry will provide the guidelines for the stakeholders to reach the successful adoption.
- In order to obtain data for readiness assessment, the survey could be conducted by structured interview form or by electronic questionnaire form alternatively.

6.4 Research Limitation

This research has developed a new readiness assessment model which called precast concrete construction readiness model (PCCRM). And the readiness of Thailand and Myanmar construction industry for the adoption of precast concrete construction in housing industry has been presented. However, there were some limitations in this research to keep the study focused on the aim of research. The followings are some limitations of the research:

- This research targets more on the use of precast concrete load bearing wall system in low-rise housing projects
- The assessment result of Thailand construction industry readiness for application of precast concrete construction was relied on five experts' opinions and perceptions which come from their experience and feeling.
- Due to limited time and cost, this model considered only four major stakeholders which were contractor, developer, regulator and customer and did not consider for designer and manufacture groups. However, there are some questions regarding the availability of these two stakeholders in the construction industry under the questionnaire of the model.
- The case studies of readiness assessment for the adoption of precast concrete method in Thailand and Myanmar construction industries were conducted with limited number of respondents and companies which are randomly selected in order to represent construction industry's readiness.

6.5 Future Study

In this research, development of the readiness assessment model and readiness assessment of Thailand and Myanmar construction industry has been explored. This section provides future study required to contribute more comprehensive knowledge.

- To develop the user-interface PCCRM Model software by using programming language such as Pythons or Visual Basis in order to show the result in the model diagram automatically, to be user-friendly and to make easy for data inputting.
- To evaluate the readiness of Thailand and Myanmar construction industry in the application of precast concrete construction based on numerous samples numbers in order to achieve more specific results.
- To improve the PCCRM Model by considering other legs for other construction stakeholders such as designer, manufacture and consultant in order to assess more detail about the readiness of those stakeholders and to provide better visual representation of overall construction industry readiness.

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VITA

NAME	Aung Phone Myint
DATE OF BIRTH	1.12.1991
PLACE OF BIRTH	Yangon, Myanmar
INSTITUTIONS ATTENDED	West Yangon Technological University, Myanmar.
HOME ADDRESS	No.6, 10 Street, 16 Wards, Hlaing Township, Yangon, Myanmar.

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APPENDIX A
Document Set for Data Collection I
(Interview Survey)

B. Questions for the Semi-structured Interview

Question for the semi-structured interview to validate the proposed model.

1. About information and background.
2. About the important level of each factor that affects the readiness of associated stakeholders and the current situation of Thailand.
3. Is each factor related or fit with current components?
4. Are questions clear to you?
5. Do you have any additional components and factors for the model?
6. Do you agree the number of maturity levels and interpretation of each maturity level for this readiness assessment model?

Interview Survey in Thailand

Part 1. Respondent's 1Information

Name :

Email :

Company Name :

Please tick the appropriate box for the following questions.

Organization:

☐ Government ☐ Contractor ☐ Developer

☐ Manufacturer ☐ Others…….

Position:

☐ Director ☐ General Manager ☐ Manager

☐ Owner ☐ Engineer ☐ Researcher

☐ Others……

Experience in construction industry:

☐ <5 years ☐ 5 – 10 years ☐ 11 – 25

☐ 26 – 35 years ☐ >35 years

Experience of participation in projects used precast concrete:

☐ <5 years ☐ 5 – 10 years ☐ 11 – 25

☐ 26 – 35 years ☐ >35 years

PART 2. Evaluation the associated factors of each component and clarification the questionnaires

Please rate the important level and current practice or situation of Thailand for each factor.

Component	CONTRACTOR										
	Questions for readiness assessment in the use of precast concrete load bearing wall	**Level of important**					**Current situation or practice**				
Process	**1. Coordination of design, manufacturing & construction** The organization conducts coordination of design, manufacturing and construction with stakeholders from the beginning of the project.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	2. Team member (client, consultant, manufacturers and contractors) involve during design stage Team members (client, consultant, manufacturers and contractors) involve during the design phase of the project to avoid problem in construction phase.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	3. Effective communication The organization is supported to obtain effective communication among client, consultants, manufacturers and contractors to avoid miscommunication. (e.g. Establishing change of command, using device & tech and etc..)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	4. Extensive planning and Scheduling The organization conducts detail and extensive planning and scheduling for construction projects to ensure precise production orders and constructing. (e.g. applying bar chart, CPM and etc.)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	5. Understanding on building regulations The organization encourages or supports the employee to learn and study about construction and building regulation of the cities before the construction activities are initiated.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

	6. Proper guideline The organization follows or conducts according to proper guideline for production and construction of precast concrete components and apply it to deliver the projects smoothly.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	7. Lean construction & Just in time (JIT) The organization applies lean construction and just in time (JIT) concept in projects.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
People	**8. Training & Education** The organization arranges or supports training and educational programs for the employees when new methods or technology are adopted in the organization.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	9. Knowledge & Awareness The organization encourages or supports the employees to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	10. Experienced & Technical capable workforce Experienced and technical capable workforces for precast concrete construction are available in the industry. (That workforce means the workers who have experience about precast construction before and the workers who can be trained technically about precast concrete construction)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never available	1. Not Sure	2. Sometime available	3. Mostly available	4. Always available
	11. Skill labor for site installation Skill labors for precast concrete construction are available to implement the installation at the site in the industry. (Skill labor mean the worker who have specialized training, or a learned skill set to perform the work or can be trained)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never available	1. Not Sure	2. Sometime available	3. Mostly available	4. Always available
	12. Continuous improvement & Learning The organization encourages or supports the employees to improve and learn continuously new things adopted by the organization.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

Management	**13. Good working collaboration, planning & strategies** The leaders manage the organization to have good working collaboration, planning and strategies for the construction project.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not sure 2. Sometimes 3. Most of the time 4. Always
	14. Business approach The senior management approaches precast concrete construction business through planning and strategy that is suitable for the business.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not sure 2. Sometimes 3. Most of the time 4. Always
	15. Top-down commitment The organization performs top-down commitment. (Top-down commitment means top management to general labors needs to work as a team and work together to achieve a goal)	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not sure 2. Sometimes 3. Most of the time 4. Always
	16. Management of supply chain and logistic The organization is capable how to manage supply chain and logistic for precast concrete construction.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree (less capable) 3.Agree (capable) 4. Strongly agree (highly capable)
	17. Risk Management The organization conducts risk management plan for the projects that provides contingency measures to deal with unexpected cases such as delay, accidences and disruption at every stage of the implementation of precast concrete construction.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not sure 2. Sometimes 3. Most of the time 4. Always
	18. Procurement strategy The organization applies procurement strategy to improve project delivery process such as tendering, cost comparison, planning, monitoring, logistics and so on.	1. Unimportant 2. Slightly 3. Moderately 4. Important 5. Very important 0. Never 1. Not sure 2. Sometimes 3. Most of the time 4. Always
	19. Precast factory & Facilities Precast concrete factories and facilities for precast concrete load bearing wall are available in the construction industry.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never available 1. Not Sure 2. Rarely available 3. Mostly available 4. Always available

Technology	**20.**	**Machineries & Equipment** Machineries and equipment for production and installation of precast concrete load bearing wall are available in the industry.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never available	1. Not Sure	2. Rarely available	3. Mostly available	4. Always available
	21.	**Design standardization & Codes** The organization conducts the precast concrete construction according to design standardization and codes of precast concrete.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	22.	**Information & Communication technology (ICT)** The organization adopts information and communication technology (ICT) to make the business easier and support the monitoring of the projects. (e.g. Using computer & electronic devices, application of BIM or etc.)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	23.	**Logistic & Transportation** The organization knows how to handle logistic and transportation of precast components when precast concrete constructions are started.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	24.	**Research & Development (R&D)** The organization focuses on R&D continuously to obtain updated innovation and improvement.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
Cost	**25.**	**Effective cost planning, control & management** The organization conducts the activities for effective cost planning, controlling and managing in the project	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	26.	**Cost of management, training, process and technology** The organization has the budget for the cost of management, training, process and technology to improve the organization and its business.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

	27. Cost of materials & Equipment The organization understand that the cost for cranes, formworks for production and other accessories are required to consider when apply precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	28. Cost of transportation The organization understands that transportation cost is required to consider when adopt precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree

Component	**REGULATOR**										
	Questions for readiness assessment in the use of precast concrete load bearing wall	**Level of Important**					**Current situation or practice**				
Process	**1. Government policy** The government promotes precast concrete construction by setting up policies regarding the application of precast concrete system	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
	2. Proper guidelines The government promotes precast concrete construction by setting up proper guidelines to achieve the best practice of precast construction and to ensure the smooth delivery process.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
	3. Government regulation The government allows to build houses with precast concrete technology according to government building regulations.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes (only some pj type)	3. Most of the time	4. Always (any kind of pj)

	4. Transportation and logistic The government rules and regulation about transportation and logistics are convenient for precast concrete construction, regarding load carrying capacity, length and size of precast components through the transportation navy and road.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
	5. Research & Development (R&D) The government establishes or supports research and development center, local research organizations and testing lab for precast concrete system.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
Technology	**6. Information & Communication technology (ICT)** The government applies information and communication technology (ICT) to be ease of business process and inspect various precast construction projects. (e.g. Using computers and electronic devices or adoption of BIM and etc.)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
	7. Design standardization and codes The government promotes precast concrete construction by developing design standardization and codes for the precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2.Slightly agree	3.Agree	4. Strongly agree
	8. Precast factory & Facilities The government knows about production process of precast concrete factory and facilities in order to inspect and permit license.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Disagree	1. Not sure	2.Slightly agree	3.Agree (know)	4. Strongly agree
	9. Machineries & Equipment The government has knowledge about various type of heavy machineries and equipment for assembling and production of precast concrete load bearing wall in order to give permission to use at the construction site.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2.Slightly agree (Know a little)	3.Agree (know)	4. Strongly agree (Know well)
	10. Tax incentive The government offers tax incentive when the precast concrete system is applied for the housing construction.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always

Strategy	**11. Developing a road map** The government promotes the adoption of precast concrete construction by developing a road map. (e.g. Malaysia government developed IBS road map to promote it)	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
	12. Promoting education about precast concrete The government promotes the education of the people regarding precast concrete construction by setting up training, academic curriculum in the university or other activities.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
	13. Creating precast concrete exhibition The government sets up or creates exhibitions regarding precast concrete technology to promote the precast concrete construction.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
	14. Increment of government project using precast concrete The government applies precast concrete system for the housing development projects. (e.g. The government pledge to construct 100,000 units with precast concrete technology)	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
	15. Environmental impact The government encourages or supports the adoption of sustainable products and process in various projects in order to reduce environmental impact from the construction activities.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
People	**16. Training & Education** The government arranges training and education programs for their staffs and construction skill workers to gain knowledge about precast concrete technology.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always
	17. Knowledge & Awareness The government encourages and supports their staffs to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Never 1. Not Sure 2. Sometimes 3. Most of the time 4. Always

	18. Experts and professional in precast The government creates a program that offers license for the engineers to be experts and professional in precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	19. Continuous improvement & learning The government encourages their staffs to improve and learn continuously new things adopted by the government.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	20. Skilled workers in precast The government creates a program that offers license for the worker to be experts and professional in precast concrete construction.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always

Component	**DEVELOPER** **Questions for readiness assessment in the use of precast concrete load bearing wall**	**Level of important**					**Current situation or practice**				
Organizational	**1. Firm's encouragement** My firm always encourages employees to try new and better ways of doing their jobs.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	2. Risk-averse culture My firm views changes as a positive factor that introduces new opportunities to gain profits.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	3. Continuous improvement & learning My firm encourages to improve and learn continuously new things adopted by the firm.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always

	4. Research & Development (R&D) My firm focuses on R&D continuously to obtain updated innovation and improvement	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	5. Knowledge & Awareness My firm encourages or supports the employees to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	6. Experience & technical capable workforce Experienced and technical capable workforces for precast concrete construction are available in the local industry. (That workforce means the workers who have experience in precast construction before and the workers who can be trained technically about precast concrete construction)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available
Resource	**7. Skilled labor for site installation** Skill labors for precast concrete construction are available to implement the installation at the site in the industry. (Skill labor mean the worker who have specialized training, or a learned skill set to perform the work)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available
	8. Training & Education My firm arranges or supports training and educational programs for the employees when new methods or technology are adopted in the organization.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
	9. Availability of precast concrete manufacturers Precast concrete manufactures which can supply the precast concrete load bearing wall are available in the local industry when the firm wants to get the precast panels for development of precast housing projects.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available
	10. Machineries & Equipment Machineries and equipment for production and installation of precast concrete load bearing wall are available in the local industry.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available

	11. Availability of experts and professions in precast Experts and profession in precast concrete are available in the local industry when the firm wants to hire for development of precast housing projects.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available
	12. Availability of contractors specialized in precast system Contractors specialized in precast system are available in the local industry when the firm wants to hire for development of precast housing projects.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Unavailable	1. Not Sure	2. Sometimes available	3. Mostly available	4. Always available
	13. Cost of factory My firm is capable to invest for precast concrete factory cost for the development of precast concrete housing project if that amount is feasible to run the business.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly agree
Market	**14. Market demand** Demand of housing requirement is high in the housing industry.	1. Unimportant	2. Slightly important	3. Moderately	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly Agree
	15. Customer attitude Customers have positive attitude. (Customers think that precast concrete houses are better quality, durability and safe to stay for them).	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree (few	3. Agree (most customer)	4. Strongly Agree (all
	16. Willingness of customer If precast concrete house price is same with the price of normal houses, it would attract customer (house buyer).	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree (few	3. Agree (most customer)	4. Strongly Agree (all
	17. Low-income groups buying power Low income groups are capable to buy affordable precast concrete houses. Lower income (300,000-600,000 MMK)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly Agree

	18. Medium-income groups buying power Medium-income groups are capable to buy affordable precast concrete houses. Medium-income group (600,000-900,000 MMK)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly Agree
External Support	**19. Government policy** The government promotes precast concrete construction by setting up policies regarding the application of precast concrete system.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	20. Incentive & Promotion The government supports incentives and promotion when the precast concrete system is applied for the housing construction.	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	21. Environmental impact The government encourages or supports the adoption of sustainable products and process in various projects in order to reduce environmental impact from the construction activities.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
	22. Acceptance of the government The government accepts to build houses by precast concrete technology according to government building regulation.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Never	1. Not sure	2. Sometimes (only some pj type)	3. Most of the time	4. Always (any kind of pj)
	23. Government Regulations The government regulations are convenient or support for the adoption of precast concrete construction.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly Agree

Component	CUSTOMER														
	Questions for readiness assessment in the use of precast concrete load bearing wall	**Level of important**					**Current situation or practice**								
Awareness	**1. Durability** I perceive that precast concrete house's structural durability are better than normal traditional house.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				
	2. Fire Resistance I aware that precast concrete houses can resist more than normal traditional houses.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				
	3. Overall cost saving I know that precast concrete houses are cost effective than other traditional houses.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				
Knowledge	**4. Environmental impact** I realize that precast concrete system can reduce the environmental impact by minimizing the waste generated from the construction activities.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				
	5. Earthquake resistance I know that precast concrete loadbearing wall houses can resist the earthquake if structural joints are designed and controlled well.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				
	6. Time saving I know that application of precast concrete system can speed up the construction speed to finish on time.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree				

	7.	**Surface Finishing** I know that the houses used precast concrete load bearing walls are not necessary to make surface finishing for wall partition.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
Liking	8.	**Low life cycle cost** I like precast concrete houses because its life cycle cost is lower than other traditional houses' life cycle cost. (e.g. No need to paint or periodically replace slats)	1. Unimportant	2. Slightly	3. Moderately	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	9.	**Quality** I like precast concrete houses than other traditional houses because materials used in precast concrete houses are better quality as it is produced in control environment.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	10.	**Thermal Efficient** I like precast concrete houses because reduced peak heating and cooling loads can be achieved because concrete reacts slowly to changes in outside temperature.	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	11.	**Benefit** I like precast concrete houses because it offers more benefits than traditional houses. (Precast concrete structures provide superior resistance to fires, natural disasters, insects and mold. Like no other building material, its resistance to rain, wind damage, earthquakes, termites and decay provides lower maintenance and insurance costs.)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
Preference	12.	**Appearance** I prefer the appearance of precast concrete houses than traditional houses. (e.g. Surface of precast concrete panels are smooth and less crack than normal brick wall)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
	13.	**Function** I prefer the functions of precast concrete houses rather than traditional houses. (e.g. fire resistance, sound control, prevent air leakage and so on)	1. Unimportant	2. Slightly important	3. Moderately important	4. Important	5. Very important	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree

	14. Acoustic insulation I prefer precast concrete houses because it offers better acoustic insulation than traditional houses.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
Conviction	**15. Price** I will purchase precast concrete house when it is available even the price is slightly higher than the price of normal house.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
	16. Safety I will buy precast concrete house because I believe or feel like precast concrete houses structure are safer to live than normal houses.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
	17. Perception I will purchase precast concrete house because of positive perception on precast concrete houses even the price is slightly higher than the price of normal house.	1. Unimportant 2. Slightly 3. Moderately 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
Purchase	**18. Payment system** A convenient payment system is available to buy houses. (e.g. credit payment system)	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
	19. Availability of loan The loan provided by financial institutions are available for house buyers.	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree 3. Agree 4. Strongly agree
	20. Experience on purchasing precast concrete house Customer (I) have purchased and used precast concrete houses	1. Unimportant 2. Slightly important 3. Moderately important 4. Important 5. Very important 0. Disagree 1. Not sure 2. Slightly agree (just involve in purchasing) 3. Agree (purchased once) 4. Strongly agree (purchased more than once)

Important level of Stakeholders

Please rate the important level of stakeholder in construction industry

No.	Stakeholders	Important Level of Stakeholder				
1.	Contractor	1. Unimportant	2.. Slightly Important	3. Moderately Important	4. Important	5. Very Important
2.	Regulator	1. Unimportant	2.. Slightly Important	3. Moderately Important	4. Important	5. Very Important
3.	Developer	1. Unimportant	2.. Slightly Important	3. Moderately Important	4. Important	5. Very Important
4.	Customer	1. Unimportant	2.. Slightly Important	3. Moderately Important	4. Important	5. Very Important

APPENDIX B
Document Set for Data Collection II
(Questionnaire survey)

Questionnaire Survey in Myanmar

Part 1. Respondent's Information

Name :

Email :

Company Name :

Please tick the appropriate box for the following questions.

Organization:

☐ Government ☐ Contractor ☐ Developer

☐ Manufacturer ☐ Others…….

Position:

☐ Director ☐ General Manager ☐ Manager

☐ Owner ☐ Engineer ☐ Researcher

☐ Others…….

Experience in construction industry:

☐ <5 years ☐ 5 – 10 years ☐ 11 – 25

☐ 26 – 35 years ☐ >35 years

Experience of participation in projects used precast concrete:

☐ <5 years ☐ 5 – 10 years ☐ 11 – 25

☐ 26 – 35 years ☐ >35 years

CONTRACTOR					
Questions for readiness assessment in the use of precast concrete load bearing wall	**Likert Scale**				
1. Coordination of design, manufacturing & construction The organization conducts coordination of design, manufacturing and construction with stakeholders from the beginning of the construction.	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
2. Effective communication The organization is supported to obtain effective communication among client, consultants, manufacturers and designers to avoid miscommunication. (e.g. Establishing change of command, using device & tech and etc.)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
3. Extensive planning and Scheduling The organization conducts detail and extensive planning and scheduling for construction projects to ensure precise production orders and constructing. (e.g. applying bar chart, CPM and etc.)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
4. Understanding on building regulations The organization encourages or supports the employee to learn and study about construction and building regulation of the cities before the construction activities are initiated.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
5. Proper guideline The organization follows or conducts according to proper guideline for production and construction of precast concrete components and apply it to deliver the projects smoothly. A **guideline** is a statement by which to determine a course of action. A guideline aims to streamline particular processes according to a set routine or sound practice.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
6. Lean construction & Just in time (JIT) The organization applies lean construction and just in time (JIT) concept in projects.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

7.	**Training & Education** The organization arranges or supports training and educational programs for the employees when new methods or technology are adopted in the organization.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
8.	**Knowledge & Awareness** The organization encourages or supports the employees to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
9.	**Experienced & Technical capable workforce** Experienced and technical capable workforces for precast concrete construction are available in the industry. (That workforce means the workers who have experience in precast construction before and the workers who can be trained technically about precast concrete construction)	0. Never available	1. Not Sure	2. Rarely available	3. Mostly available	4. Always available
10.	**Skill labor for site installation** Skill labors for precast concrete construction are available to implement the installation at the site in the industry. (Skill labor mean the worker who have specialized training, or a learned skill set to perform the work or can be trained)	0. Never available	1. Not Sure	2. Rarely available	3. Mostly available	4. Always available
11.	**Continuous improvement & Learning** The organization encourages or supports the employees to improve and learn continuously new things adopted by the organization.	0. Never	1. Not Sure	2. Sometimes	3. Most of the time	4. Always
12.	**Good working collaboration, planning & strategies** The leaders manage the organization to have good working collaboration, planning and strategies for the construction project.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
13.	**Business approach** The senior management approaches precast concrete construction business through planning and strategy that is suitable for the business.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

14.	**Top-down commitment** The organization performs top-down commitment. (Top-down commitment means top management to general labors needs to work as a team and work together to achieve a goal)	0. Never	1. Rarely	2. Sometimes	3. Most of the time	4. Always
15.	**Management of supply chain and logistic** The organization is capable how to manage supply chain and logistic for precast concrete construction.	0. Disagree	1. Not sure	2. Slightly agree (less capable)	3.Agree (capable)	4. Strongly agree (highly capable)
16.	**Risk Management** The organization conducts risk management plan for the projects that provides contingency measures to deal with unexpected cases such as delay, accidences and disruption at every stage of the implementation of precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
17.	**Procurement strategy** The organization applies procurement strategy to improve project delivery process such as tendering, cost comparison, planning, monitoring, logistics and so on.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
18.	**Precast factory & Facilities** Precast concrete factories and facilities for precast concrete load bearing wall are available in the construction industry.	0. Unavailable	1. Not Sure	2. Sometime available	3. Mostly available	4. Always available
19.	**Machineries & Equipment** Machineries and equipment for production and installation of precast concrete load bearing wall are available in the industry.	0. Unavailable	1. Not Sure	2. Sometime available	3. Mostly available	4. Always available
20.	**Information & Communication technology (ICT)** The organization adopts information and communication technology (ICT) to make the business easier and support the monitoring of the projects. (e.g. Using computer & electronic devices, application of BIM or etc.)	0. Never	1. Not sure	2. Sometimes	3. Most of the	4. Always

21.	**Logistic & Transportation** The organization knows how to handle logistic and transportation of precast components when precast concrete constructions are started.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
22.	**Research & Development (R&D)** The organization focuses on R&D continuously to obtain updated innovation and improvement.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
23.	**Effective cost planning, control & management** The organization conducts the activities for effective cost planning, controlling and managing in the project	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
24.	**Cost of management, training, process and technology** The organization has the budget for the cost of management, training, process and technology to improve the organization and its business.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
25.	**Cost of materials & Equipment** The organization understands that the cost for cranes, formworks for production and other accessories are required to consider when apply precast concrete construction	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
26.	**Cost of transportation** The organization understands that transportation cost is required to consider when adopt precast concrete construction	0. Don’ t aware	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree

REGULATOR					
Questions for readiness assessment in the use of precast concrete load bearing wall	**Likert Scale**				
1. Government policy The government promotes precast concrete construction by setting up policies regarding the application of precast concrete system	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
2. Proper guidelines The government promotes precast concrete construction by setting up proper guidelines to achieve the best practice of precast construction and to ensure the smooth delivery process.	0. Never	1. Not sure	2. Sometime	3. Most of the time	4. Always
3. Government regulation The government allows to build houses with precast concrete technology according to government building regulations.	0. Never	1. Not sure	2. Sometimes (only some pj type)	3. Most of the time	4. Always (any kind of pj)
4. Transportation and logistic The government rules and regulation about transportation and logistics are convenient for precast concrete construction, regarding load carrying capacity, length and size of precast components through the transportation navy and road.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
5. Research & Development (R&D) The government establishes or supports research and development center, local research organizations and testing lab for precast concrete system.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
6. Design standardization and codes The government promotes precast concrete construction by developing design standardization and codes for the precast concrete construction.	0. Disagree	1. Not sure	2.Slightly agree	3.Agree	4. Strongly agree

7.	**Precast factory & Facilities** The government knows about production process of precast concrete factory and facilities in order to inspect and permit license. (If the government don't know about precast concrete technology, they will not be capable to inspect whether precast components are produced according to standardization or not to achieve standardized quality)	0. Disagree	1. Not sure	2.Slightly agree (Know a little)	3.Agree (know)	4. Strongly agree (Know well)
8.	**Machineries & Equipment** The government has knowledge about various type of heavy machineries and equipment for assembling and production of precast concrete load bearing wall in order to give permission to use at the construction site.	0. Disagree	1. Not sure	2.Slightly agree (Know a little)	3.Agree (know)	4. Strongly agree (Know well)
9.	**Tax incentive** The government offers tax incentive when the precast concrete system is applied for the housing construction. (e.g. Full exemption from government levy was given to housing developers in the private sector who utilize precast concrete components exceeding 50%)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
10.	**Developing a road map** The government promotes the adoption of precast concrete construction by developing a road map. (e.g. Malaysia government developed IBS road map to promote it)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
11.	**Promoting education about precast concrete** The government promotes the education of the people regarding precast concrete construction by setting up training, academic curriculum in the university or other activities.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
12.	**Creating precast concrete exhibition** The government sets up or creates exhibitions regarding precast concrete technology to promote the precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

13.	**Increment of government project using precast concrete** The government applies precast concrete system for the housing development projects. (e.g. The government pledge to construct 100,000 units with precast concrete technology)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
14.	**Environmental impact** The government encourages or supports the adoption of sustainable products and process in various projects in order to reduce environmental impact from the construction activities. (e.g. the government acknowledge precast concrete construction contributions toward green and sustainable construction in the construction environment)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
15.	**Training & Education** The government arranges training and education programs for their staffs and construction skill workers to gain knowledge about precast concrete technology.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
16.	**Knowledge & Awareness** The government encourages and supports their staffs to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
17.	**Experts and professional in precast** The government creates a program that offers license for the engineers to be experts and professional in precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
18.	**Continuous improvement & learning** The government encourages their staffs to improve and learn continuously new things adopted by the government.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
19.	**Skilled workers in precast** The government creates a program that offers license for the worker to be experts and professional in precast concrete construction. (e.g. driver for heavy equipment, skilled labors for production and assembling precast components and so on)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always

DEVELOPER					
Questions for readiness assessment in the use of precast concrete load bearing wall	**Likert Scale**				
1. Firm's encouragement My firm always encourages employees to try new and better ways of doing their jobs.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
2. Risk-averse culture My firm views changes as a positive factor that introduces new opportunities to gain profits.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
3. Continuous improvement & learning My firm encourages to improve and learn continuously new things adopted by the firm.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
4. Research & Development (R&D) My firm focuses on R&D continuously to obtain updated innovation and improvement	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
5. Knowledge & Awareness My firm encourages or supports the employees to gain knowledge and awareness about potential advantages and hindrance of precast concrete construction.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
6. Experience & technical capable workforce for design Experienced and technical capable workforces for the design of precast concrete construction are available in the local industry.	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available

7.	**Skilled labor for site installation** Skill labors for precast concrete construction are available to implement the installation at the site in the industry. (Skill labor mean the worker who have specialized training, or a learned skill set to perform the work)	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available
8.	**Training & Education** My firm arranges or supports training and educational programs for the employees when new methods or technology are adopted in the organization.	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
9.	**Availability of precast concrete manufacturers** Precast concrete manufactures which can supply the precast concrete load bearing wall are available in the local industry when the firm wants to get the wall for development of precast housing projects.	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available
10.	**Machineries & Equipment** Machineries and equipment for production and installation of precast concrete load bearing wall are available in the local industry.	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available
11.	**Availability of experts and professions in precast concrete** Experts and profession in precast concrete are available in the local industry when the firm wants to hire for development of precast housing projects.	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available
12.	**Availability of contractors specialized in precast system** Contractors specialized in precast system are available in the local industry when the firm wants to hire for development of precast housing projects.	0. Unavailable	1. Not sure	2. Sometimes available	3. Mostly available	4. Always available

13.	**Cost of factory** My firm is capable to invest for precast concrete factory cost for the development of precast concrete housing project if that amount is feasible to run the business. (Semi precast factory cost = 800 MB)	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly agree
14.	**Market demand** Demand of housing requirement is high in the housing industry.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly Agree
15.	**Customer perception** Customers have positive perception. (Customers think that precast concrete houses are better quality, durability and safe to stay for them).	0. Disagree	1. Not sure	2. Slightly agree (few customer)	3. Agree (most customer)	4. Strongly Agree (all customer)
16.	**Willingness of customer** If precast concrete house price is same with the price of normal houses, it would attract customer (house buyer)	0. Disagree	1. Not sure	2. Slightly agree (few customer)	3. Agree (most customer)	4. Strongly Agree (all customer)
17.	**Low-income groups buying power** Low income groups are capable to buy affordable precast concrete houses Lower income (300,000-600,000 MMK)	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly Agree
18.	**Medium-income groups buying power** Medium-income groups are capable to buy affordable precast concrete houses Medium-income group (600,000-900,000 MMK)	0. Disagree	1. Not sure	2. Slightly agree (need lone)	3. Agree	4. Strongly Agree

19.	**Government policy** The government promotes precast concrete construction by setting up policies regarding the application of precast concrete system (e.g. To increase productivity, reduce labor incentive or every public project needs to use at least 50% precast concrete components in the project)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
20.	**Incentive & Promotion** The government supports incentives and promotion when the precast concrete system is applied for the housing construction. (e.g. If precast concrete components are use more than 50% of the project, tax exemption will be obtained)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
21.	**Environmental impact** The government encourages or supports the adoption of sustainable products and process in various projects in order to reduce environmental impact from the construction activities. (e.g. the government acknowledge precast concrete construction contributions toward green and sustainable construction in the construction environment)	0. Never	1. Not sure	2. Sometimes	3. Most of the time	4. Always
22.	**Government Regulations** The government allows or accepts to construct buildings by precast concrete technology according to its building regulation.	0. Never	1. Not sure	2. Sometimes (only some kind of pjs)	3. Most of the time (most of the pjs)	4. Always (all kind of pjs)

CUSTOMER (House buyers)					
Questions for readiness assessment in the use of precast concrete load bearing wall	**Likert Scale**				
1. Durability I perceive that precast concrete house's structural durability are better than normal traditional house.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
2. Fire Resistance I aware that precast concrete houses can resist to fire more than normal traditional houses.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
3. Environmental impact I realize that precast concrete system can reduce the environmental impact by minimizing the waste generated from the construction activities.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
4. Earthquake resistance I know that precast concrete load-bearing wall houses can resist the earthquake if structural joints are designed and controlled well.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
5. Smooth and ledge free finishing I know that the houses used precast concrete load bearing walls offer smooth and ledge free walls that are easy to clean.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
6. Quality I like precast concrete houses than other traditional houses because materials used in precast concrete houses are better quality as it is produced in control environment.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
7. Thermal Efficient I like precast concrete houses because reduced peak heating and cooling loads can be achieved as concrete reacts slowly to changes in outside temperature.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree

8.	**Benefit** I like precast concrete houses because it offers more benefits than traditional houses. (Precast concrete structures provide superior resistance to fires, natural disasters, insects and mold. Like no other building material, its resistance to rain, wind damage, earthquakes, termites and decay provides lower maintenance and insurance costs.)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
9.	**Appearance** I prefer the appearance of precast concrete houses than traditional houses. (e.g. Surface of precast concrete panels are smooth and less crack than normal brick wall)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
10.	**Function** I prefer precast concrete houses function rather than traditional houses. (e.g. fire resistance, sound control, prevent air leakage and etc.)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
11.	**Acoustic insulation** I prefer precast concrete houses because it offers better acoustic insulation than traditional houses.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
12.	**Price** I will purchase precast concrete house when it is available even the price is similar with the price of normal house.	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
13.	**Life safety and health** I will buy precast concrete house because I believe or feel like precast concrete houses structure offers life safety and health to live than normal houses. (Structure of precast concrete load bearing wall houses is like rectangular frame and resilient structure that can resist more lateral load, fire, blast, hurricane and improve indoor air quality than normal frame system)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree

14.	**Attitude** I will purchase precast concrete house because of my positive attitude on precast concrete houses. (I think that precast concrete houses are better quality, durability and safe to stay for them)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
15.	**Payment system** A convenient payment system is available for customers (house buyer) to buy houses. (e.g. credit payment system or another)	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
16.	**Availability of loan** The loan provided by financial institutions are available for customers (house buyers).	0. Disagree	1. Not sure	2. Slightly agree	3. Agree	4. Strongly agree
17.	**Experience on purchasing precast concrete house** I have ever purchased and used precast concrete houses.	0. Disagree	1. Not sure	2. Slightly agree (just involve in purchasing)	3. Agree (purchased once)	4. Strongly agree (purchased more than once)

APPENDIX C
Detail of Data Analysis

A. Experts score for important level of factors

		No.	Factors	Experts					Mean
				E1	E2	E3	E4	E5	
Developer	Organization	1	Firm's encouragement	4	4	4	3	4	3.8
		2	Risk-averse culture	4	4	4	4	4	4.0
		3	Continuous improvement & learning	4	4	4	4	4	4.0
		4	Research & Development (R&D)	3	4	3	3	4	3.4
		5	Knowledge & Awareness	4	5	5	4	5	4.6
	Resource	6	Experience & technical capable workforce	4	5	4	4	5	4.4
		7	Skilled labor for site installation	4	3	3	4	4	3.6
		8	Training & Education	4	5	4	4	4	4.2
		9	Availability of precast concrete manufacturers	5	5	4	5	4	4.6
		10	Machineries & Equipment	4	4	4	5	4	4.2
		11	Availability of experts and professions in precast	5	4	5	5	4	4.6
		12	Availability of contractors specialized in precast system	4	4	5	5	4	4.4
		13	Cost of factory	2	2	2	3	3	2.4
	Market	14	Market demand	5	5	5	5	5	5.0
		15	Customer attitude	5	4	4	4	2	3.8
		16	Willingness of customer	5	4	4	4	4	4.2
		17	Low-income groups buying power	4	4	4	4	4	4.0
		18	Medium-income groups buying power	4	4	4	4	4	4.0
	External support	19	Government policy	2	3	2	2	1	2.0
		20	Incentive & Promotion	2	3	2	2	1	2.0
		21	Environmental impact	2	2	2	2	3	2.2
		22	Government regulation	5	5	5	4	5	4.8

		No.	Factors	Experts					Mean
				E1	E2	E3	E4	E5	
Regulator	Process	1	Government policy	2	2	2	3	1	2.0
		2	Proper guidelines	2	2	2	3	1	2.0
		3	Government regulation	5	5	5	4	4	4.6
		4	Transportation and logistic	2	4	3	4	3	3.2
	Technology	5	Research & Development (R&D)	2	4	2	3	1	2.4
		6	Design standardization & Codes	4	3	3	3	4	3.4
		7	Precast factory & Facilities	2	1	2	3	2	2.0
		8	Machineries & Equipment	2	5	4	3	2	3.2
		9	Information and communication technology (ICT)	2	2	2	2	1	1.8
	Strategy	10	Tax incentive	2	2	2	2	2	2.0
		11	Developing a road map	2	4	3	3	1	2.6
		12	Promoting education about precast concrete	2	3	2	3	3	2.6
		13	Creating precast concrete exhibition	2	2	2	2	2	2.0
		14	Increment of government project using precast concrete	2	5	3	5	4	3.8
		15	Environmental impact	2	2	2	2	2	2.0
	People	16	Training & Education	2	2	2	2	2	2.0
		17	Knowledge & Awareness	2	2	3	3	3	2.6
		18	Experts and professional in precast	3	3	2	3	3	2.8
		19	Continuous improvement & learning	2	3	3	3	3	2.8
		20	Skilled workers in precast	2	5	3	3	3	3.2

		No.	Factors	Experts					Mean
				E1	E2	E3	E4	E5	
Contractor	Process	1	Coordination of design, manufacturing & construction	4	5	4	5	4	4.4
		2	Effective communication	3	3	4	4	2	3.2
		3	Extensive planning & Scheduling	4	4	3	3	5	3.8
		4	Understanding on building regulations	5	5	4	3	5	4.4
		5	Proper guideline	4	4	3	3	4	3.6
		6	Lean Construction & Just in time (JIT)	5	4	3	3	3	3.6
	People	7	Training & Education	4	5	5	3	4	4.2
		8	Knowledge & Awareness	4	5	3	4	4	4.0
		9	Experienced & Technical capable workforce	5	4	3	3	4	3.8
		10	Skill labor for site installation	4	4	3	3	5	3.8
		11	Continuous improvement & learning	4	5	3	4	3	3.8
	Management	12	Good working collaboration, Planning & Strategies	4	4	4	5	4	4.2
		13	Business approach	4	4	2	4	4	3.6
		14	Top-down commitment	5	3	3	3	4	3.6
		15	Management of supply chain and logistic	4	5	3	4	4	4.0
		16	Risk management	4	4	2	3	4	3.4
		17	Procurement strategy	3	5	3	4	4	3.8
	Technology	18	Precast factory & facilities	4	5	5	4	2	4.0
		19	Machineries & Equipment	4	5	5	4	3	4.2
		20	Information & Communication technology (ICT)	3	3	2	3	4	3.0
		21	Logistic & Transportation	4	5	4	4	4	4.2
		22	Research & Development (R&D)	3	4	3	4	4	3.6
	Cost	23	Effective cost planning, control & management	4	4	3	4	4	3.8
		24	Cost of management, training, process and technology	3	4	3	3	4	3.4
		25	Cost of materials and equipment	4	5	4	4	4	4.2
		26	Cost of transportation	4	5	4	3	4	4.0

		No.	Factors	Experts					Mean
				E1	E2	E3	E4	E5	
Customer	Awareness	1	Durability	4	5	4	4	4	4.2
		2	Fire Resistance	3	3	3	3	3	3.0
		3	Overall cost saving	1	1	1	2	1	1.2
	Knowledge	4	Environmental impact	2	2	2	2	2	2.0
		5	Earthquake resistance	3	2	3	3	2	2.6
		6	Time saving	1	2	2	2	2	1.8
		7	Smooth and ledge free finishing	2	3	3	3	2	2.6
	liking	8	Low life cycle cost	1	2	1	2	1	1.4
		9	Quality	4	3	4	3	4	3.6
		10	Thermal Efficient	3	2	2	3	4	2.8
		11	Benefit	4	3	4	4	4	3.8
	Preference	12	Appearance	4	3	4	3	4	3.6
		13	Function	3	3	4	3	4	3.4
		14	Acoustic insulation	2	3	3	3	2	2.6
	Conviction	15	Price	4	4	5	4	4	4.2
		16	Life safety and health	2	2	3	3	2	2.4
		17	Attitude	3	4	4	3	3	3.4
	Purchase	18	Payment system	4	5	4	4	4	4.2
		19	Availability of loan	5	5	4	4	4	4.4
		20	Experience on purchasing precast concrete house	3	4	3	4	5	3.8

B. Calculation of Components' Weight

		No.	Factors	Expert Mean Score	Component mean score	Component weight
Developer	Organization	1	Firm's encouragement	3.800	3.960	0.265
		2	Risk-averse culture	4.000		
		3	Continuous improvement & learning	4.000		
		4	Research & Development (R&D)	3.400		
		5	Knowledge & Awareness	4.600		
	Resource	6	Experience & technical capable workforce	4.400	4.050	0.271
		7	Skilled labor for site installation	3.600		
		8	Training & Education	4.200		
		9	Availability of precast concrete manufacturers	4.600		
		10	Machineries & Equipment	4.200		
		11	Availability of experts and professions in precast	4.600		
		12	Availability of contractors specialized in precast system	4.400		
		13	Cost of factory	2.400		
	Market	14	Market demand	5.000	4.200	0.281
		15	Customer attitude	3.800		
		16	Willingness of customer	4.200		
		17	Low-income groups buying power	4.000		
		18	Medium-income groups buying power	4.000		
	External support	19	Government policy	2.000	2.750	0.184
		20	Incentive & Promotion	2.000		
		21	Environmental impact	2.200		
		22	Government regulation	4.800		
				84.200	14.960	1.000

		No.	Factors	Expert Mean Score	Component mean score	Component weight
Customer	Awareness	1	Durability	4.200	3.600	0.179
		2	Fire Resistance	3.000		
	Knowledge	3	Environmental impact	2.000	2.400	0.120
		4	Earthquake resistance	2.600		
		5	Smooth and ledge free finishing	2.600		
	liking	6	Quality	3.600	3.400	0.169
		7	Thermal Efficient	2.800		
		8	Benefit	3.800		
	Preference	9	Appearance	3.600	3.200	0.160
		10	Function	3.400		
		11	Acoustic insulation	2.600		
	Conviction	12	Price	4.200	3.333	0.166
		13	Life safety and health	2.400		
		14	Attitude	3.400		
	Purchase	15	Payment system	4.200	4.133	0.206
		16	Availability of loan	4.400		
		17	Experience on purchasing precast concrete house	3.800		
				56.600	20.067	1.000

		No.	Factors	Expert Mean Score	Component mean score	Component weight
Contractor	Process	1	Coordination of design, manufacturing & construction	4.40	3.83	0.200
		2	Effective communication	3.20		
		3	Extensive planning & Scheduling	3.80		
		4	Understanding on building regulations	4.40		
		5	Proper guideline	3.60		
		6	Lean Construction & Just in time (JIT)	3.60		
	People	7	Training & Education	4.20	3.92	0.205
		8	Knowledge & Awareness	4.00		
		9	Experienced & Technical capable workforce	3.80		
		10	Skill labor for site installation	3.80		
		11	Continuous improvement & learning	3.80		
	Management	12	Good working collaboration, Planning & Strategies	4.20	3.77	0.196
		13	Business approach	3.60		
		14	Top-down commitment	3.60		
		15	Management of supply chain and logistic	4.00		
		16	Risk management	3.40		
		17	Procurement strategy	3.80		
	Technology	18	Precast factory & facilities	4.00	3.80	0.198
		19	Machineries & Equipment	4.20		
		20	Information & Communication technology (ICT)	3.00		
		21	Logistic & Transportation	4.20		
		22	Research & Development (R&D)	3.60		
	Cost	23	Effective cost planning, control & management	3.80	3.85	0.201
		24	Cost of management, training, process and technology	3.40		
		25	cost of materials and equipment	4.20		
		26	cost of transportation	4.00		
				99.60	19.17	1.00

		No.	Factors	Expert Mean Score	Component mean score	Component weight
Regulator	Process	1	Government policy	2.000	2.950	0.271
		2	Proper guidelines	2.000		
		3	Government regulation	4.600		
		4	Transportation and logistic	3.200		
	Tech:	5	Research & Development (R&D)	2.400	2.750	0.253
		6	Design standardization & Codes	3.400		
		7	Precast factory & Facilities	2.000		
		8	Machineries & Equipment	3.200		
	Strategy	9	Tax incentive	2.000	2.500	0.230
		10	Developing a road map	2.600		
		11	Promoting education about precast concrete	2.600		
		12	Creating precast concrete exhibition	2.000		
		13	Increment of government project using precast concrete	3.800		
		14	Environmental impact	2.000		
	People	15	Training & Education	2.000	2.680	0.246
		16	Knowledge & Awareness	2.600		
		17	Experts and professional in precast	2.800		
		18	Continuous improvement & learning	2.800		
		19	Skilled workers in precast	3.200		
				51.200	10.880	1.000

C. Calculation of Stakeholders' Weight

Stakeholders	Expert					Average Mean Score	Stakeholders' weight
	E1	E2	E3	E4	E5		
Regulator	4	2	3	3	3	3.00	0.203
Developer	5	4	4	5	5	4.60	0.311
Contractor	3	3	3	4	3	3.20	0.216
Customer	5	3	4	5	3	4.00	0.270
						14.80	1.00

D. Expert score and calculation of readiness percentage for Thailand construction Industry

		Factors	Component weight	Experts					Mean Score	Component mean score	Readiness of component (%)	Readiness of Contractor (%)
				E1	E2	E3	E4	E5				
Contractor	Process	F1	0.200	2	2	3	3	3	2.6	17.6	62.9%	72.4%
		F2		2	3	2	3	3	2.6			
		F3		4	2	4	2	3	3.0			
		F4		3	3	4	3	2	3.0			
		F5		4	2	3	3	3	3.0			
		F6		4	4	2	3	4	3.4			
	People	F7	0.205	4	2	3	3	3	3.0	15.0	75.0%	
		F8		4	2	3	2	2	2.6			
		F9		3	2	3	4	4	3.2			
		F10		4	3	4	4	3	3.6			
		F11		3	2	2	2	4	2.6			
	Management	F12	0.196	3	2	3	3	3	2.8	17.4	72.5%	
		F13		3	3	3	2	4	3.0			
		F14		3	2	3	2	3	2.6			
		F15		4	3	3	4	3	3.4			
		F16		3	2	2	3	3	2.6			
		F17		4	3	3	2	3	3.0			
	Technology	F18	0.198	4	4	3	4	3	3.6	14.8	74.0%	
		F19		4	3	4	4	3	3.6			
		F20		2	1	2	3	3	2.2			
		F21		4	3	4	4	3	3.6			
		F22		2	1	2	2	2	1.8			
	Cost	F23	0.201	2	3	2	3	4	2.8	12.4	77.5%	
		F24		2	3	2	2	2	2.2			
		F25		4	3	4	4	4	3.8			
		F26		4	3	4	4	3	3.6			

		Factors	Component weight	Experts					Avg: Mean Score	Component mean score	Readiness of component (%)	Readiness of Regulator (%)
				E1	E2	E3	E4	E5				
Regulator	Process	F1	0.271	1	0	0	0	0	0.2	8.20	51%	47%
		F2		1	1	0	0	0	0.4			
		F3		4	4	4	4	4	4.0			
		F4		3	3	4	4	4	3.6			
	Tech:	F5	0.253	1	2	1	2	2	1.6	9.60	60%	
		F6		4	2	4	2	2	2.8			
		F7		4	2	2	3	2	2.6			
		F8		4	2	2	3	2	2.6			
	Strategy	F9	0.230	0	0	0	0	0	0.0	9.40	39%	
		F10		0	0	0	0	0	0.0			
		F11		3	1	3	3	1	2.2			
		F12		3	2	2	0	2	1.8			
		F13		4	3	3	3	2	3.0			
		F14		3	2	2	3	1	2.4			
	People	F15	0.246	3	2	3	2	2	2.4	8.20	41%	
		F16		3	2	3	2	2	2.4			
		F17		1	0	1	0	0	0.4			
		F18		3	2	2	3	2	2.4			
		F19		1	1	1	0	0	0.6			

		Factors	Component weight	Experts					Avg: Mean Score	Component mean score	Readiness of component (%)	Readiness of Developer (%)
				E1	E2	E3	E4	E5				
Developer	Organization	F1	0.265	3	1	3	4	3	2.8	13.8	69.0%	70.0%
		F2		3	3	3	2	2	2.6			
		F3		3	2	3	4	3	3.0			
		F4		2	2	3	4	2	2.6			
		F5		3	2	3	4	2	2.8			
	Resource	F6	0.271	4	3	3	3	3	3.2	27.0	84.4%	
		F7		3	3	3	4	3	3.2			
		F8		3	2	3	3	2	2.6			
		F9		4	4	3	4	3	3.6			
		F10		4	4	4	4	3	3.8			
		F11		4	4	4	4	3	3.8			
		F12		3	3	4	4	3	3.4			
		F13		4	2	4	3	4	3.4			
	Market	F14	0.281	4	4	2	3	3	3.2	15.2	76.0%	
		F15		4	2	3	2	2	2.6			
		F16		4	3	2	2	2	2.6			
		F17		4	4	2	4	2	3.2			
		F18		4	4	3	4	3	3.6			
	External support	F19	0.184	4	0	2	0	0	1.2	6.6	41.3%	
		F20		0	0	0	0	0	0.0			
		F21		2	1	1	2	1	1.4			
		F22		4	4	4	4	4	4.0			

		Factors	Component weight	Experts					Avg: Mean Score	Component mean score	Readiness of component (%)	Readiness of Customer (%)
				E1	E2	E3	E4	E5				
Customer	Awareness	F1	0.179	2	4	1	1	1	1.8	4.20	52.5%	50.3%
		F2		4	2	3	1	2	2.4			
	Knowledge	F3	0.120	1	2	0	2	2	1.4	5.00	41.7%	
		F4		0	3	1	1	1	1.2			
		F5		3	2	3	2	2	2.4			
	Liking	F6	0.169	2	1	3	3	1	2.0	5.60	46.7%	
		F7		2	2	3	0	1	1.6			
		F8		1	2	3	2	2	2.0			
	Preference	F9	0.160	1	2	3	1	1	1.6	5.00	41.7%	
		F10		2	2	3	2	1	2.0			
		F11		2	2	0	2	1	1.4			
	Conviction	F12	0.166	3	2	2	3	2	2.4	5.00	41.7%	
		F13		2	2	2	0	1	1.4			
		F14		1	1	1	2	1	1.2			
	Purchase	F15	0.206	4	2	4	4	3	3.4	8.40	70.0%	
		F16		4	1	3	3	2	2.6			
		F17		0	3	3	3	3	2.4			

Industry	Stakeholder	Components	Component's Weight	Component (%)	Readiness of Stakeholder (%)	Stakeholder's Weight	Readiness of Construction Industry (%)
Thailand Precast Concrete Construction	Contractor	Process	0.200	63%	72%	0.216	61%
		People	0.205	75%			
		Management	0.196	73%			
		Technology	0.198	74%			
		Cost	0.201	78%			
	Regulator	Process	0.271	51%	47%	0.203	
		Technology	0.253	60%			
		Strategy	0.230	39%			
		People	0.246	41%			
	Developer	Organization	0.265	69%	70%	0.311	
		Resource	0.271	84%			
		Market	0.281	76%			
		External support	0.184	41%			
	Customer	Awareness	0.179	53%	50%	0.270	
		Knowledge	0.120	42%			
		Liking	0.169	47%			
		Preference	0.159	42%			
		Conviction	0.166	42%			
		Purchase	0.206	70%			

E. Rating scale and calculation of readiness percentage for Myanmar construction industry

		Factors	Component weight	Respondent			Average Mean Score	Component Mean Score	Readiness of component (%)	Readiness of Regulator (%)
				A	B	C				
Regulator	Process	F1	0.271	2	0	0	0.67	7.667	48%	34%
		F2		1	1	1	1.00			
		F3		4	3	4	3.67			
		F4		3	2	2	2.33			
	Tech:	F5	0.253	2	0	0	0.67	6.000	38%	
		F6		0	0	0	0.00			
		F7		3	2	3	2.67			
		F8		3	2	3	2.67			
	Strategy	F9	0.230	0	0	0	0.00	4.333	18%	
		F10		0	0	0	0.00			
		F11		2	0	2	1.33			
		F12		2	0	2	1.33			
		F13		2	1	2	1.67			
		F14		0	0	0	0.00			
	People	F15	0.246	2	2	2	2.00	6.000	30%	
		F16		2	2	2	2.00			
		F17		0	0	0	0.00			
		F18		2	2	2	2.00			
		F19		0	0	0	0.00			

		Factor	Component weight	Company															Average Mean Score	Component Mean Score	Readiness of Component (%)	Readiness of Contractor (%)
				A	B	C	D	E	F	G	H	I	J	K	L	M	N	O				
Contractor	Process	F1	0.200	3	4	3	2	2	3	2	3	3	3	3	2	4	3	3	2.87	14.267	59%	53%
		F2		3	4	3	3	2	2	3	2	3	3	3	2	2	3	2	2.67			
		F3		3	4	3	3	2	3	3	2	3	3	3	2	3	3	3	2.87			
		F4		2	4	3	3	2	3	2	1	2	3	3	2	2	2	3	2.47			
		F5		0	3	1	1	0	0	0	1	1	1	0	0	4	0	1	0.87			
		F6		2	3	3	3	2	2	2	2	3	3	3	2	3	3	2	2.53			
	People	F7	0.205	2	4	2	3	2	3	2	2	3	2	2	0	2	3	2	2.27	8.867	44%	
		F8		0	2	0	2	0	0	0	2	0	2	2	0	2	0	0	0.80			
		F9		2	1	1	3	2	1	1	1	2	2	2	1	2	2	1	1.60			
		F10		2	2	1	3	2	2	1	2	2	2	2	1	2	2	1	1.80			
		F11		2	3	2	3	2	3	3	2	2	3	2	2	2	3	2	2.40			
	Management	F12	0.196	3	2	3	3	3	3	3	2	3	3	3	3	3	3	3	2.87	12.933	54%	
		F13		0	3	1	0	0	1	0	2	0	1	2	0	4	0	0	0.93			
		F14		3	3	4	1	3	3	3	2	2	2	3	3	3	3	2	2.67			
		F15		2	2	3	3	0	2	2	3	3	3	2	0	4	3	0	2.13			
		F16		2	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2.20			
		F17		3	4	3	3	0	2	3	2	0	3	2	2	2	2	1	2.13			
	Technology	F18	0.198	2	3	2	2	2	1	1	2	2	2	2	1	2	2	2	1.87	8.267	41%	
		F19		2	3	2	2	2	3	3	2	2	2	3	2	3	3	3	2.47			
		F20		2	2	2	0	0	3	0	0	0	2	2	0	0	1	0	0.93			
		F21		2	3	0	3	2	2	2	3	2	2	3	0	4	3	3	2.27			
		F22		2	2	0	0	0	0	0	1	1	1	0	1	2	1	0	0.73			
	Cost	F23	0.201	3	4	3	4	4	3	3	2	3	3	3	2	3	3	3	3.07	10.800	68%	
		F24		0	3	0	2	0	3	0	1	0	2	3	2	3	3	0	1.47			
		F25		3	4	3	3	1	3	3	3	3	3	3	3	4	3	3	3.00			
		F26		3	4	3	3	3	4	3	3	3	4	3	3	4	3	3	3.27			

		Factor	Component weight	Respondent															Average Mean Score	Component Mean Score	Readiness of Component (%)	Readiness of Customer (%)
				A	B	C	D	E	F	G	H	I	J	K	L	M	N	O				
Customer	Awareness	F1	0.179	1	1	1	2	0	2	0	0	0	1	0	0	3	2	2	1.00	1.667	21%	26%
		F2		1	1	1	2	1	1	0	0	0	0	0	0	0	0	3	0.67			
	Knowledge	F3	0.120	3	3	3	3	2	1	0	0	0	2	0	0	2	0	2	1.40	4.067	34%	
		F4		3	1	1	3	2	1	0	0	0	2	0	0	2	2	0	1.13			
		F5		3	3	2	3	3	1	0	0	0	2	0	0	2	2	2	1.53			
	Liking	F6	0.169	3	1	1	2	2	1	2	0	0	0	0	0	2	2	2	1.20	3.067	26%	
		F7		1	1	2	3	2	1	1	0	0	0	0	0	2	0	1	0.93			
		F8		1	1	1	2	1	1	0	0	0	2	0	0	2	0	3	0.93			
	Preference	F9	0.160	3	2	1	3	1	1	2	0	0	0	0	0	1	2	0	1.07	3.000	25%	
		F10		1	1	2	3	1	1	1	0	0	2	0	0	2	0	1	1.00			
		F11		1	1	1	3	2	1	1	0	0	2	0	0	2	0	0	0.93			
	Conviction	F12	0.166	1	1	1	3	1	1	2	1	1	1	0	0	2	2	1	1.20	2.733	23%	
		F13		1	1	1	2	1	1	0	0	0	0	0	0	2	1	1	0.73			
		F14		1	1	1	2	1	1	1	0	0	0	0	0	2	2	0	0.80			
	Purchase	F15	0.206	1	1	3	3	3	2	2	1	2	2	2	2	1	2	2	1.93	3.400	28%	
		F16		1	3	3	3	1	3	2	1	1	0	0	1	1	0	0	1.33			
		F17		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0.13			

		Factor	Component weight	Company										Average Mean Score	Component Mean Score	Readiness of Component (%)	Readiness of Developer (%)
				A	B	C	D	E	F	G	H	I	J				
Developer	Organization	F1	0.265	3	3	2	2	2	3	3	0	3	3	2.40	9.700	49%	37%
		F2		3	3	2	3	3	3	3	3	3	3	2.90			
		F3		2	2	2	3	2	3	3	2	3	2	2.40			
		F4		0	1	0	0	0	0	0	1	1	2	0.50			
		F5		0	2	1	2	2	2	2	0	2	2	1.50			
	Resource	F6	0.271	2	0	2	0	2	1	1	2	2	2	1.40	13.900	43%	
		F7		1	0	1	2	2	1	2	1	1	2	1.30			
		F8		2	2	0	2	2	3	2	0	2	2	1.70			
		F9		2	1	3	2	2	1	2	2	2	2	1.90			
		F10		1	3	3	2	3	3	3	1	3	3	2.50			
		F11		1	0	0	2	2	1	3	2	3	2	1.60			
		F12		2	0	0	2	2	2	2	1	2	2	1.50			
		F13		1	2	4	0	3	0	3	0	3	4	2.00			
	Market	F14	0.281	0	0	0	2	2	2	0	1	3	2	1.20	5.800	29%	
		F15		2	0	1	0	2	1	2	1	1	2	1.20			
		F16		0	1	1	2	2	1	2	0	2	1	1.20			
		F17		0	0	0	0	0	0	0	0	1	0	0.10			
		F18		2	2	2	2	2	2	2	2	3	2	2.10			
	External support	F19	0.184	0	0	0	0	2	0	0	0	0	0	0.20	3.500	22%	
		F20		0	0	0	0	0	0	0	0	0	0	0.00			
		F21		0	0	0	2	0	0	0	0	0	0	0.20			
		F22		2	4	4	2	2	2	3	4	4	4	3.10			

Industry	Stakeholder	Components	Component's Weight	Component (%)	Readiness of Stakeholder (%)	Stakeholder's Weight	Readiness of Construction Industry (%)
Myanmar Precast Concrete Construction	Contractor	Process	0.200	59%	53%	0.204	37%
		People	0.205	44%			
		Management	0.196	54%			
		Technology	0.198	41%			
		Cost	0.201	68%			
	Regulator	Process	0.271	48%	34%	0.185	
		Technology	0.253	38%			
		Strategy	0.230	18%			
		People	0.246	30%			
	Developer	Organization	0.265	49%	37%	0.333	
		Resource	0.271	43%			
		Market	0.281	29%			
		External support	0.184	22%			
	Customer	Awareness	0.179	21%	26%	0.278	
		Knowledge	0.120	34%			
		Liking	0.169	26%			
		Preference	0.159	25%			
		Conviction	0.166	23%			
		Purchase	0.206	28%			