A SYSTEM DYNAMICS MODEL TO ASSESS THE INTERRELATIONSHIP BETWEEN DIFFERENT KNOWLEDGE AREAS OF PMBOK IN A CONSTRUCTION PROJECT

ZAINAB BINTI A MALIK

Master of Science

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

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ZAINAB BINTI A MALIK

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ABSTRAK

Projek pembinaan yang berjaya adalah sukar untuk dicapai dalam industri pembinaan yang dinamik dan kompleks. Pengurusan projek yang berjaya memerlukan penerapan bidang-bidang pengetahuan dalam pengurusan projek semasa menguruskan projek dan menyelesaikan projek seperti yang dijadualkan. Institut Pengurusan Projek (PMI) telah mengeluarkan sepuluh bidang pengetahuan yang saling berkaitan antara satu sama lain sebagai panduan kepada pengurusan projek. Ia juga telah menjelaskan langkah demi langkah dengan jelas bagi setiap bidang pengetahuan dalam Badan Pengurusan Projek Pengetahuan (PMBOK). Penyelidikan yang sedia ada telah memberi tumpuan kepada bidang-bidang pengetahuan tersebut, sama ada secara berasingan atau individu untuk menyelesaikan masalah dalam sesuatu projek. Keadaan ini boleh menyebabkan keputusan yang diambil dalam satu bidang pengetahuan membawa masalah kepada bidangan pengetahuan yang lain kerana bidang-bidang pengetahuan yang ada kaitan dengan masalah dilihat secara berasingan. Oleh sebab itu, kajian ini ditubuhkan untuk menyelesaikan masalah pengurus projek yang membuat keputusan yang kurang tepat disebabkan melihat bidang pengetahuan yang berkaitan secara berasingan dengan cadangan untuk mengenal pasti kesalinghubungan dan hubungan antara bidang pengetahuan yang berbeza di PMBOK dalam projek pembinaan. Bidang-bidang pengetahuan yang digunakan dalam kajian ini adalah pengurusan perolehan, pengurusan skop, pengurusan pemegang saham, pengurusan bersepadu, dan pengurusan sumber manusia. Kelima-lima bidang pengetahuan ini diambil daripada kajian kes. Kemudian, gambarajah gelung penyebab dibina untuk melihat hubungan antara bidang pengetahuan tersebut dan diterjemahkan ke dalam rajah stok dan aliran untuk membangunkan model sistem dinamik. Selepas itu, model sistem dinamik dibina dan model diuji. Hanya selepas itu, informasi yang diperlukan dimasukkan kedalam model dan cadangan strategi dirumuskan. Melalui model sistem dinamik, pengurus projek boleh menghubungkan antara bidang-bidang pengetahuan yang berbeza dan yang berkaitan, mensimulasikan dan kemudian melihatnya dalam gambaran yang lebih besar dan jelas. Simulasi menerangkan kelakuan projek dan hubungannya antara proses projek pra pembinaan dengan bidang pengetahuan yang berbeza dalam pengurusan projek. Setelah dianalisis semua data penting menggunakan model sistem dinamik, didapati bahawa projek pra pembinaan telah ditangguhkan sekitar 38.7% daripada jadual. Ini disebabkan oleh beberapa aktiviti yang boleh dilakukan serentak, tetapi dilakukan satu persatu dan memanjangkan masa. Selain itu, pengurus projek meletakkan bilangan pekerja yang tidak mencukupi untuk menyiapkan projek seperti yang dijadualkan. Melalui model sistem dinamik, model boleh mencadangkan kemungkinan strategi untuk mengurangkan masa penyelesaian projek iaitu dengan menggabungkan beberapa aktiviti yang boleh dijalankan serentak dan menambah jumlah pekerja yang cukup untuk menyelesaikan projek dalam masa yang diberikan. Akhirnya, model sistem dinamik dalam kajian ini boleh menunjukkan ramalan jika keputusan aktiviti digabung dan pekerja ditambah, masalah kelewatan projek selesai boleh dikurangkan.

ABSTRACT

Successful construction projects are difficult to achieve in the dynamic and complex construction industry. Successful project management requires the application of knowledge areas in project management while managing projects and completing projects as scheduled. The Project Management Institute (PMI) has issued ten areas of knowledge that are interconnected with each other as a guide to project management. It has also explained step by step clearly for every area of knowledge in the Project Management Body of Knowledge (PMBOK). Existing research has focused on these areas of knowledge, either separately or individually to solve problems in a project. This situation can cause results taken in one area of knowledge to bring problems to other knowledge areas because the areas of knowledge related to the problem are seen separately. Therefore, this study was set up to solve the problem of project managers who made ineffective decision making due to looking at areas of knowledge related separately with the proposal to identify the connectivity and the relationship between different knowledge areas of PMBOK in construction projects. The areas of knowledge used in this study are procurement management, scope management, stakeholder management, integrated management, and human resource management. These five areas of knowledge are derived from a case study. Then, a causal loop is constructed to see the relationship between the knowledge field and is translated into stock and flow diagrams to develop a system dynamic model. After that, the system dynamic model was built and the model was tested. Only then, the required information is included and the recommendation strategy is formulated. Through the system dynamic model, project managers can link between different and relevant areas of knowledge, simulate and view them in larger descriptions. Simulation explains the behavior of the project and its relation to the pre-construction project process with different areas of knowledge in project management. After analyzing all the important data using the system dynamic model, it was found that pre-construction projects had been postponed around 38.7% from the schedule. This is due to several activities that can be done simultaneously, but done one by one. Additionally, project managers put inadequate number of employees to complete the project as scheduled. Through the system dynamic model, models can suggest possible strategies for reducing project completion time by combining several activities that can be carried out simultaneously and increase the number of employees sufficient to complete the project in a given time. Finally, the system dynamic model in this study can show forecasts if the results of the combined activities and the employees are added, the problem of completion of the project completion can be reduced.

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LIST OF ABBREVIATIONS

ANS	American National Standard
ANSI	American National Standard Institute
CIDB	Construction Industry Development Board
CPM	Critical Part Method
DES	Discrete Event Simulation
GDP	Gross Domestic Product
MCS	Monte Carlo Simulation
PMBOK	Project Management Body Of Knowledge
PMI	Project Management Institute
SD	System Dynamics
WBS	Work Breakdown Structure

CHAPTER 1

INTRODUCTION

1.1 Introduction

The construction industry is one of the most important industries in a nation (Ali Khan et al., 2014). Based on the Construction Industry Development Board (CIDB), The construction industry in Malaysia is a major economic engine for the entire economy (CIDB, 2015). A country cannot grow without its development. Infrastructures are built to support and influence the nation's economy and improve the quality of life of its population. Construction industry's function is to convert the people's need into a construction development project such as hospitals, schools, housing, roads, and many more. Construction industry is the main focus within the development process of a nation (Waris et al, 2014). Without construction, development cannot happen.

1.2 Background of Study

Construction industry always involves numerous activities and budget. At the same time, it also produces substantial profits. According CIDB (2015), Malaysia's construction sector had contributed about 4 per cent every year to Malaysia's economy from 2013 until 2015. Even though, it does not contribute too much in number but actually it greatly assists in economic development. Ibrahim et al. (2010) claimed that for a country in the process of development, the advancement in construction sector is very crucial and is given much emphasis. It is necessary to keep the construction performance progressing.

According to CIDB, construction sector is within the top five sectors that has contributed to the Malaysia's Gross Domestic Product (GDP) in value (CIDB, 2015). The first sector is services followed by manufacturing, agriculture, mining and quarrying, and lastly construction. Although the construction sector is the fifth ranking sector that contributes to Malaysia's GDP in value, but construction sector contributes at the first ranking in GDP growth. Based on Figure 1.1, GDP growth by construction sector is 10.8% in 2013 and increased in 2014 by 11.8%, followed by services, manufacturing, agriculture, and mining and quarrying in 2013. In 2014, the construction sector ranked first, continued by services, manufacturing, mining and quarrying, and agriculture.

Sector	2013	2014
Agriculture	1.9	2.1
Mining and Quarrying	1.2	3.3
Services	6.0	6.5
Manufacturing	3.4	6.2
Construction	10.8	11.8

Figure 1.1 GDP growth by economic activity
Source: CIDB (2015)

Furthermore, many other developing countries are concerned about the contribution of construction sector towards the nation's economy. For example, Nguyen et al. (2004) stated that the industry and construction sector in Vietnam are the main contributors in enhancing the economy by contributing 39% in 2002. Ghana is also facing the same situation. By referring to Ghana's Statistical Service in 2013, the construction sectors' revenue had contributed a lot to the improvement of gross domestic product (GDP) which is an increase from 7.6 % in 1996 to 9.9 % in 2011 (Amoatey et al., 2015). Then the percentage rose higher by 12.6 % in 2013 (Amoatey et al., 2015). Vietnam and Ghana are also considered as developing countries (World Bank, 2014). The construction industry is one of the industries that puts a lot of effort in the development of economy and country (Shehu, 2014). It shows that, construction industry performance can have a huge influence and importance toward the economy and the country.

In addition, beside the contribution of construction industry in developing countries, construction industry also plays an important role in the contribution to developed countries. It is because construction industries in South Korea has significant relationship with country's economy too. The importance of the construction industry in South Korea can be described, if there is a problem in the process of construction, it will have a bad impact on the country's economy (Cho, 2011). South Korea is not listed in the list of developing countries (World Bank, 2014) because South Korea is included within one of the developed countries. In addition, construction industry also is the biggest contributor to economic growth in Europe and the US by representing 10-11% and 13% of GDP (Mohamad Bohari et al., 2015). This indicates that construction industry is not only important for the economy of developing countries only, but also important in the economy of developed countries too. Thus, economy plays an important role in determining a country's level of development.

Besides that, the benefits of construction industry are not simply enjoyed by construction industry itself and the nation's economy, but also accepted and enjoyed by others industries. Amoatey et al. (2015) stated that construction industry contributes a good influence toward various industrial development with an increasing percentage from 29.8 % in 1993 to 34.3 % in 2000 and the percentage is expected to increase again in 2011 with 37.4 %. That is because construction industry also gives benefit to other industries like manufacturing industry. Construction sector assists the manufacturing sector through the demand for steel, iron, and cement for the various construction phases of development (Mohamad Bohari et al, 2015). Therefore, if the country is concerned toward the development of the construction industry, other industries' growth also has to improve along the way.

However, construction performance would be reduced dramatically if construction performance is not well maintained. This is evident as the construction sector contribution to GDP has slowly gone down from 11.8% in 2014 to 8.2% in 2015 (CIDB, 2015). It is important to ensure the performance of the construction industry is in good condition, and the main source of ensuring the performance of the construction industry is in good condition is the project manager. According to Yang et al. (2017), among all the professionals in the construction project, project manager is the key figure in determining the project performance whether it is good or not. In general, the failed project is due to ineffective project management (Varajao et al., 2017).

Rework, last minute changes, over schedule, over budget, and lack of resources are some of the issues that are faced by a project manager in monitoring the project in project management field (Gebrehiwet and Luo, 2017). Throughout the year, the various problems are faced by the construction project but today, its more challenging than previous years due to competitive force, market demand, nation's economy and its fluctuation (Samantra et al., 2017). The challenging project's environments today makes the role of project manager become more challenging and stressful (Yang et al., 2017). Project construction is one that involve complexity and uncertainty in the environment of a project (Yang et al. 2017).

Furthermore, many construction projects now suffer from delays and this causes negative impacts on projects (Gebrehiwet and Luo, 2017). However, the occurrence of delay in construction projects is not a sudden occurrence but is caused by a variety of previous events (Hsu et al., 2017). Most of the problems are interrelated with other. Therefore, in order for the project manager to manage the project effectively, there is a need to define and understand the interconnectivity and interrelationship between different knowledge areas of project management that are involved. Especially in industrial sectors such as construction, as it is known that it is involved with its complex, ever-changing and dynamic processes (Yang et al., 2017).

In an effort to understand the different knowledge areas of project management, as a guideline, the Project Management Institute (PMI) through its Project Management Body of Knowledge (PMBOK) had come out with ten knowledge areas of project management as a standard guideline for project managers (Ferreira et al., 2017). Those ten knowledge areas are project integration management, project cost management, project human resources management, project scope management, project quality management, project communication management, project time management, project procurement management, project risk management, and project stakeholder management.

PMI is the pioneer in introducing professionalism in project management worldwide and has helped project managers in managing the project successfully (Pinto and Winch, 2016). Besides that, Varajao (2016) had stated that the discussion of each knowledge area in PMBOK in conducting a big framework can cater to various areas in the project management profession. The knowledge areas in PMBOK are a combination of proven traditional practices that are widely used and become as innovative practices that appear in the project management profession (Varajao et al., 2017). Addition, PMBOK is a powerful guideline that is able to control of all relevant dimensions in project management (Murguia et al., 2017)

1.3 Problem Statement

PMBOK is recognized as good practices for project management practitioners as it had fulfilled the international standards (Varajao, 2016). Due to various knowledge areas of project management in PMBOK as a guide to plan and manage projects, many researchers have analysed the relationship between PMBOK's knowledge field on the success of the project. For example, Tengan and Aigbavboa (2017) stated that poor participation of stakeholders in the project may have contributed to the failure in project delivery. Besides, the performance of the project depends on where stakeholders and organizations are mutually satisfied with the whole process (Oppong et al., 2017). Gebrehiwet and Luo (2017) conclude that time, cost, quality, and stakeholder are the PMBOK knowledge areas that mostly affect the success of the project.

Therefore, there is no specialization in the most of the critical areas of knowledge. In fact, as PMBOK state, it is the responsibility of the project team to decide on how much to develop each field of knowledge in each particular project (Ruiz-Martin and Poza, 2015). A successful construction project is considered when it is completed within time, cost, and stakeholder requirement of its quality. However, completing the project in time is a frequent indicator of efficiency (Hsu et al., 2017). Based on Gebrehiwet and Luo (2017), even common indicators for a successful construction project is finished on time, within cost, and according to stakeholders requirement, but most of the project face delays.

In order to complete the project on time, the interconnectivity and interrelationship between related elements that can cause the construction project delay have to be understood (Hsu et al., 2017). Hence, the project process can be understood as a whole and becomes easier to manage as well as to make decisions. However, some project managers are more likely to solve the problem in the project separately. As a result, when changes are made in one section, it is likely to change on the other side. It can solve problems in the short term but it can make the problem bigger in the long run and affect the project delay at the end.

Traditional tools like Work Breakdown Structure (WBS) and Critical Part Method (CPM) are not supportive to deal with dynamic project. Wang et al. (2017) stated that traditional or conventional tools are unable to cope with uncertainty and dynamic situation because these tools follow a linear logic to bring a project back on track. However, Li et al. (2018) suggested to use system dynamics tool to deal with complex project because this tool is suitable in science and engineering as well as in education or in real life application. Besides that, this tool can complement with the complex system with the integration of modeling and logic model. Therefore, the objective of this study is to integrate both system dynamics with PMBOK in order to understand the interrelationship between different knowledge areas of project management in a construction project. According to Dumrk et al. (2017) stated that more knowledge areas of a project manager can be interrelated, the more knowledge's the project manager can contribute to sustain the project outcomes.

1.4 Objective of Study

This study focuses on the interconnectivity and interrelationship in terms of Project Management Body of Knowledge areas (PMBOK) by using system dynamics as the methodology. Therefore, the objectives of this study are:

1. To identify the interconnectivity and interrelationship between five knowledge areas in PMBOK.
2. To develop a system dynamics model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK.
3. To make recommendations of strategy implication based on the interconnectivity and the interrelationship between project management knowledge areas.

1.5 Scope of Study

This study uses PMBOK published by Project Management Institute (PMI) of fifth edition in 2013 as the basics for the project management's knowledge areas. The knowledge areas that are involved are five from ten knowledge areas in PMBOK, which are project integration management, project scope management, project human resource management, project procurement management, and project stakeholder management.

The knowledge areas are selected based on the knowledge areas that are related within the case study used in this study.

Besides that, this study focuses on construction projects. The construction project, there are many processes that are involved within it. However, this study only focuses on processes taken before beginning the construction process, which is pre-construction project process. Because according to Heravi et al. (2015) the highest level of capability that have impacts on the final project is at the start of the project and reduces when the project takes place. Besides that, this study focuses on a case study in a construction project that are one of the well-known construction company in Malaysia. The name of the construction company is confidential.

The interviewee in this study is a project manager because this person is the person in charge directly to the project planning until its project completion. This is to ensure the data that are collected is valid and achieves the objectives of the study.

1.6 Significance of Study

The significance of the study, firstly is to show the importance in looking at the relationship between knowledge areas that cause the problem as a whole in order to understand the sequence of the problem before making a decision. System dynamics model in this study can show that, if the problem happens due to delays, that does not mean the solution is also around the time management. But the project manager need to understand the interrelationship between knowledge areas that cause project delay. From the interrelationship between those knowledge areas, the project manager can manage the project effectively because it enables the manager to know if one knowledge areas changes, how it will affect other knowledge areas that are related.

Moreover, through the interrelated knowledge areas, project manager can predict the output of the project clearly. It is because project construction is one of the complex projects and it often involves with unpredictable changes in project. So it is very important for the project manager to understand the interrelated knowledge areas that are related. Then it can help the manager to understand the factor of change in the project.

Moreover, the main thing for this research is, it can provide suggestions based on system dynamics model on interrelationship and interconnectivity between project management's knowledge areas. It facilitates the work of a manager to manage the construction project efficiently.

Lastly, from this research, the strategic model that is proposed can potentially reduce time allocated for the implementation strategy of the project by applying the model, before it can be applied in the real project application. The model can help to increase the confidence level of the project manager before implementing the suggested strategy.

1.7 Operational Definition

Definition of the ten knowledge areas in PMBOK from the fifth edition (PMI, 2013):

1. Project integration management: The processes and activities and activities required to identify, define, consolidate, and coordinate various project management processes and activities within the project management process group.
2. Project scope management: The process required to ensure that the project covers all the required work, and remove unnecessary work, to successfully complete the project.
3. Project time management: The processes required to manage the project that are timely.
4. Project cost management: Process involving planning, estimates, budgets, and any efforts that can control the cost of the project to be completed within approved estimates.
5. Project quality management: Organizational processes and activities that implement quality policies, objectives and responsibilities, then the project can meet its requirements.
6. Project human resource management: The process that organize, manage, and lead the human capital in the project.
7. Project communication management: The process required to ensure the planning, collection, creation, and variety of project information is timely and appropriate.

8. Project risk management: The process of carrying out planning, identification, analysis, risk response planning and risk control on a project.
9. Project procurement management: The process required to purchase or require the necessary products, services, or decisions from outside the project team.

Project stakeholder management: The process required to identify all parties or organizations affected by this project, analyse the stakeholders' expectations and project its effects. As well as building appropriate management strategies for stakeholders to facilitate decision-making and implementation.

1.8 Thesis Outline

This thesis is organized into six chapters. Chapter One is about the introduction of this thesis, followed by Chapter Two which is about literature review from other researchers that are related to this study. Chapter Three explains on methodology that this study uses and next Chapter Four explains about how the model is constructed. While in Chapter Five describes about the suggested model and data analysis. This thesis ends with a conclusion and discussion about this research in Chapter Six.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses about literature review of previous studies that are significant to support this study. This chapter starts with a discussion on the construction project performance, followed by management of construction project. The subsequent sections discusses the implementation of Project Management Body of Knowledge (PMBOK), the application of system dynamics in construction management and ends with a summary of this chapter.

2.2 Construction Project Performance

2.2.1 Uncertainty in Construction Projects

The construction project is known for its complex and dynamics project environment. Mok et al. (2015) pointed out that a construction project involves a complex environment. It is because a construction project needs to deal with various parties and subsystems like human factor and schedule commitment. Typically, a project construction team is involved with different organizations and authorities that need to work together in completing the project such as clients, contractors, sub-contractors, consultants, and suppliers. Most of those authorities are involved from the beginning of the project. Stakeholders in the project construction like clients, consultants, and contractors are important because these authorities can influence the project success (Jalal and Shoar, 2017).

Moreover, the complex interaction between various phases of project influence the factors in the project construction that leads to a dynamic project (Moradi et al., 2015). Construction project also has to deal with the pressure to deliver the project within limited time, allocated budget, and project requirement. The successful project is determined by delivering the project within the given time, budget and quality standards that are specified by the customer (Mpofu et al., 2017). A project is translated as a set of activities with a start time and end time and its aim is to achieve a certain goal of project that is unique (PMI, 2013).

Normally, the project construction processes can be divided into three main project phases - pre-construction, construction and post construction (Gebrehiwet and Luo, 2017). All of these phases need to be managed and controlled effectively by a project manager for successful completion of a construction project. From the three phases, pre-construction phase is the crucial part that needs greater emphasis. According to Heravi et al. (2015) the highest level of capability that have impacts on the final project is at the start of the project and reduces when the project takes place. It is because at this point project needs are defined, work break down structure is created, the project requirement is measured clearly, and further negotiation between parties are involved (PMI, 2013).

Moreover, there are many important things that the project managers need to do at the beginning of the project. Especially the need to deal with various stakeholders to achieve a mutual agreement. Construction project involves with various different parties of stakeholder as separate organization entities but work for the same project (Miller et al., 2009). Many stakeholders, individuals and groups are involved in construction project planning and each has their own roles, needs and objectives. Because stakeholders in construction projects are many and different, this makes the agreement in construction projects difficult to achieve (Heravi et al., 2015). Agreements made at the start of the project should involve all parties or stakeholders in connection with project and project managers are tasked to control this situation.

Moreover, project manager also needs to give more time and concern in the pre-construction phase of project and to identify project activities in order to develop a better planning (Coffey, 2015). The pre-construction phase is given importance in the project. It is because important discussions, planning, and decision will be made at this phase. This phase will affect the completion of the project at the end. Improper planning at the initial stage can cause delays in various stages (Abbas et al., 2016). In addition, the pre-construction phase is easier to understand by referring at Figure 2.1.

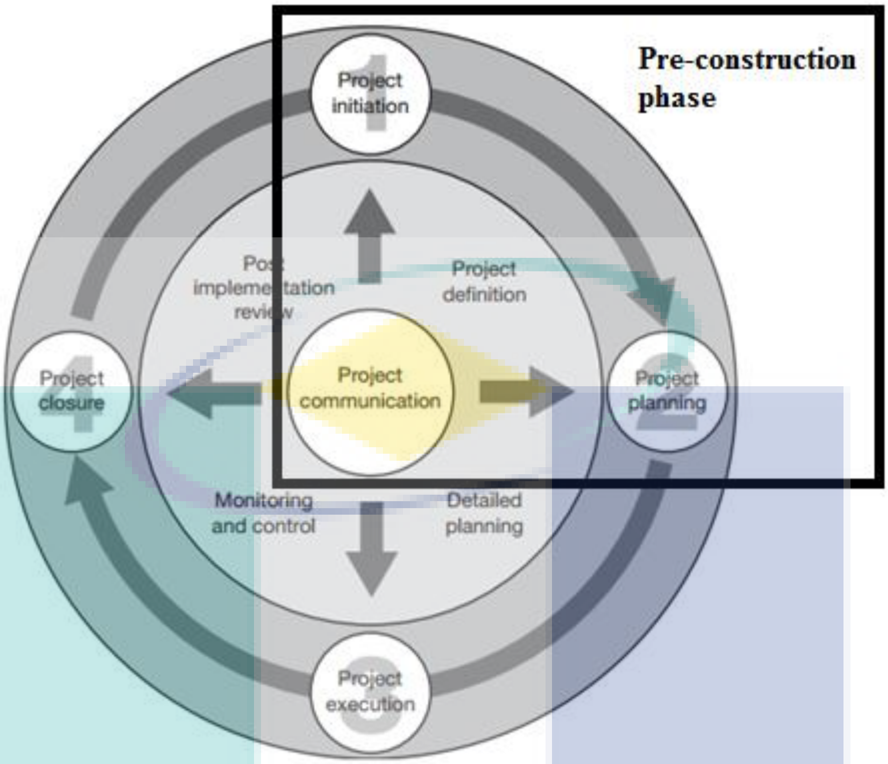


Figure 2.1 Pre-construction phase in project life cycle
Source: Westland (2006)

Based on Figure 2.1, project life cycle starts from project initiation and is followed by project planning, project execution, and ends at project closure (Westland, 2006). The pre-construction phases is under initiation and planning project process. In these beginning of project processes, the involvement of stakeholders, risk, and uncertainty are high (PMI, 2013). According to Figure 2.2, the impact of risk and uncertainty are high at the beginning of project process and reduces along the project time. It is because it is possible to change in order to define the exact project decision that are agreed by different parties that are involved in the project. Each stakeholder has his or her own desire on the project that makes frequent change happen. Fageha and Aibinu (2013) stated that, the concern of project stakeholder at the early project stage is crucial to prevent the project of being in risk condition during execution stage. This situation leads to the scope and planning of the project become uncertain and unpredictable at the beginning.

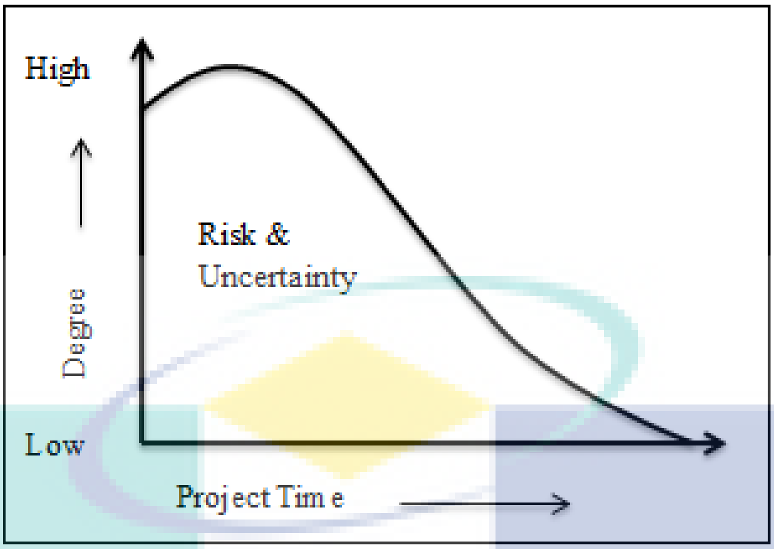


Figure 2.2 Impact of risk and uncertainty over project time
Source: PMI (2013)

According to Fageha and Aibinu (2013) unclear scope project definition at the early stage is the frequent cause of problems that happen during construction project development process. Mirza et al. (2013) also said that most of the factors that contribute to project failure is because of project scope being undefined during the early stage of project. Those elements happen in pre-construction project process. If the problems are not managed properly, the project schedule will ultimately need to be extended.

Besides that, Mirza et al. (2013) mentioned that three elements that are necessary toward project success are identifying the activities that are involved at the beginning stage, understanding the project objective, and defining the action of project performance. However, due to the high risk, high stake involving stakeholder, and high uncertainty in the pre-construction process, it makes those elements difficult to achieve. High uncertainty can influence the extent of unexpected change. This situation makes the project become worse. It is compulsory to understand the factors that are related to unexpected change in order to improve the construction performance (Wang et al., 2017).

Moreover, unexpected changes that occur in the project are common and capable to lead the project to be delayed (Iannone et al., 2015). Delay is something crucial that needs to be prevented because it can reduce the project performance as project time is included in the specification of a successful project. Franco et al. (2018)

stated that the successful project is determined by delivering the project within time, budget and standard quality that are specified by the customer. These three elements are interdependent (Hu and He, 2014). However, most of construction project suffer with project delay (Gebrehiwet and Luo, 2017).

Aziz and Abdel-Hakam (2016) mentioned that, delay is one of the biggest problem in a construction project and affects every party in construction project. Besides, the meaning of project it, is a group of activities that has starting time and ending time to complete the project based on the project's objective (PMI, 2013). If the project is extended, the other activities also need to be extended. In this pre construction phase, many aspects can contribute to the extension of the project. Therefore, project managers need to calculate those related things into account in order to prevent the project from being delayed.

2.2.2 Construction Project Delay

The construction sector is a worthy sector in a nation. However, it is difficult to conduct and maintain the construction performance. Time is one of the significant indicators to measure the level of project performance. Many researchers' state that the success of a project depends on the project's time, budget and quality of the yield. According to Meng (2012) time, cost, and quality are the common indicators to measure the level of the construction performance. The indicator for each project performance varies such as cost performance, time performance, quality performance, safety performance, rework and change order. Chou and Yang (2013) stated that the most significant indicators for project performances are cost performance and time performance.

However, the most significant indicators for project construction performance is time performance. It is because, according to Senouci et al. (2016), project construction is frequently experiencing time delay compared to cost overruns, which are 72% projects are time delayed and 54% projects are cost overrun. Besides that, most of the clients do not want to know whether the construction project has enough budget or have any problems to complete the project. But the important thing is the project need to be completed on time as scheduled. It shows that time is very crucial and widely used as the term in increasing the performance of each construction project. Besides, project delay has a very high capability in reducing the project performance and in some cases, it ultimately leads to project failure.

Project delay in construction is a common issue that is faced by most of construction companies in our country and even almost every country in the world. According to Aziz (2013) time is one of the significant indicators to measure the level of project success. Project delay in Egypt is a common issue that is faced by most of construction sectors. Report by Marzouk and El-Rasas (2014) also mention that project construction delay in Egypt is normal. However, in Malaysia delay is one of the critical problems that are faced by most of the construction sectors (Alaghbari et al., 2007). Construction projects in Jordan also face the same problems cited by Suez et al. (2007). Senouci et al. (2016) mention that new project mostly face delay problems.

As explained by Aziz (2013), project delay is the situation when a project is not completed within specific time that is agreed at beginning of the contract. Similarly Sweis et al. (2007) described that delay as an activity or event that is beyond the period required that is agreed in the agreement. Each project has its own schedule and deadline for each activity. If some activities in the project are extended from the time allocated; even for a very short period of time is capable to cause the project to be extended or delayed.

A study by Meng (2012) stated that 67 construction projects (64.4%) were delayed and 37 projects (35.6%) were on schedule. According Senouci et al. (2016) stated in their research that 19 projects (24.7%) were delayed from 2000 to 2006 but 58 projects (75.3%) were delayed from 2007 to 2013. As a result, the contribution of the construction sector to GDP had slowly decreased from 3.6% in 1999 to 2.9% in 2004 (Ibrahim et al., 2010) and will further decrease if this problem is not overcome correctly. Because Aziz and Abdel-Hakam (2016) declared that time in a construction project is considered as money.

Meanwhile, the delay in the construction project can influence the performance of time, cost, and quality of the construction project (Aziz, 2013). The delay problem is very crucial to overcome, as it gives bad impact on the project performance. As stated by Ibrahim et al. (2010) most of the construction projects in Malaysia that are already completed actually is facing issues of over schedule, over budget, less quality of work, and does not fulfill the requirement of the project aim. It is difficult to keep the performance of the construction project on track even though these projects have already been completed.

The adverse effects of project delay do not only affect the management of time alone. However, this disaster also affects and influences the stakeholder expectation, client's trust, and the company's performance as a whole. Holt (2013) pointed out that project delay can lead to project failure. Project failure does not only have bad influence towards stakeholders, but also leads to other problems such as workers losing their jobs, the wastage of company money and clients lose their trust. It destroys the good relationship between suppliers and clients. It will take a long period to renew their relationship (Holt, 2013).

Normally a project delay can also affect the extended time of project completion, increase in the budget, not working smoothly, reduced productivity, third party claims for warranty, fighting between workers, and terminating the contract (Aziz, 2013). As agreed by Holt (2013), construction project delay leads to increased cost, cost fluctuation, and lost of customer's trust.

The project delay could reduce the benefit of project (Sweis et al., 2007) and sometimes it even make the project be useless without any profit gained and the most feared outcome, it can lead to the project incurring losses. It will portray a negative image towards the construction company (Holt, 2013). In addition, within the long term ultimately, it can be a nightmare for the poor performance of the economy of the nation. Therefore, it is important to avoid the delay of project construction.

2.3 The Management of Construction Project

2.3.1 Factors That Cause Construction Project Delay

In order to improve the construction project performance and to prevent the project delay within the dynamic, complexity, and uncertainty in the construction project environment, there is a need to look into the factors that contribute to the construction project delay. A lot of efforts that are used time by time to solve the problem that were causing delayed in construction project, however construction project delay still happens (Alzara et al., 2016).

On the other hand, in some cases, the current technology has already been implemented to prevent project delay but the project delay is still inevitable. A discussion by Ibrahim et al. (2010) argued that Construction Industry Development Board (CIDB) has proposed to the Malaysia Construction Industry (MCI) to use technology machinery, innovation of the method and techniques to improve the construction industry's reputation. In contrary, the reality proves that project delays still happen. It shows that, if the technology is already upgraded to hasten the project process, but if other related elements that contribute to construction project delay is not solved, then the same problem will still happen.

Table 2.1 shows some of the studies that have listed down the major causes of project delay in construction project. The five biggest causes of construction project delay is uncertain weather condition, lack of construction materials, slow in decision making (owner), poor supervision at project site, shortage of employees (Aziz and Abdel-Hakam, 2016). In addition, Marzouk and El-Rasas (2014) stated that financially poor and delay in payment by owners are the major causes that cause the project delay, followed by change in scope of work, inappropriate surrounding condition, less worker productivity, and inappropriate phases in planning and scheduling. Each of these cases involves different type of management areas like cost management, time management, scope management, risk management, and quality management.

However, Aziz (2013) stated the list of delay in payment, various methods in bribes, lack of material, inappropriate in planning and scheduling, and poor in site supervision are the top variables that contribute to project delays. Same as to Doloi et al. (2012), Sweis et al. (2007), and Alaghbari et al. (2007) mentioned in their studies, the factors that causes a construction project delay are a lot, but most of the factors are interrelated between each other. It seems there are too many causes of project delay that should be managed by the project manager in an effort to prevent project delay and ultimately achieve the project goal.

Moreover, based on Table 2.1, each causes of project delay involves different type areas of management areas in order to solve this problem of project delay. Many tasks are needed to manage and supervise the project manager. In connection with that, some knowledge of management are needed by project manager to manage the project effectively and be an effective project manager. Therefore, in order to control these causes, there is a need for an effective project manager who knows as much as he or she can on various issues on knowledge of management and to define the best solution for project delay.

Table 2.1 Top five causes of project construction delay

Authors	**Major causes in project delay**	**Areas of management**
Aziz and Abdel-Hakam (2016)	Weather condition Lack of construction materials Slow in decision making (owner) Poor supervision at project site Shortage of employees	Risk Cost Stakeholder Communication Human Resource
Marzouk and El-Rasas (2014)	Poor in financial and delay in payment by owner Change in scope of work Inappropriate surrounding condition Less of worker productivity Inappropriate in planning and scheduling	Cost and Time Scope Risk Quality Time
Aziz (2013)	Delay in payment Various methods in bribes Lack of material Inappropriate in planning and scheduling Poor in site supervision	Time Stakeholder Cost Time Quality
Doloi et al. (2012)	Delay in delivery of material in site Delay in drawing Lack of financial issues by contractor The scope of work change Take time in seeking local authorities	Time Time Cost Scope Time
Sweis et al. (2007)	Financial problem by contractor Change in scope of work Inappropriate planning and scheduling by contractor Labor lack of skill Lack of technical knowledge by contractor	Cost Scope Time Human resources Human resources
Alaghbari et al. (2007)	Financial problem by owner Economy problems Financial difficulties by contractor Slow in decision-making Poor instruction Shortage of materials in market	Cost Risk Cost Time Communication Risk

2.3.2 The Need for an Effective Project Manager

Project manager is the person who is assigned by the management as the project leader for the assigned team in order to achieve the project goals (PMI, 2013). Normally project manager is introduced as a project leader in the project site. The basic roles of most project manager are managing the project in order to achieve the projects' goal. Which are to ensure the project stays under budget, completed within time schedule, fulfil the quality expectation, and deliver the project safely (Mpofu et al., 2017).

Project manager needs to control the project period because as most people know, project is a group of activities that is conducted within a specific time to achieve certain goals. PMI (2013) mentions that project are activities that are conducted over a temporary period to develop a special product, service, or result. If the project is conducted over the time provided, it may lead the project into various problems and issues. Anything that happens within the project completion period, the project manager is the main source of explanation, and will be questioned by top management because project manager is the leader and the person in charge directly towards the overall project performance.

Jalal and Shoar (2017) reported that factors influencing project delay can be divided into four categories; contractor's factors, client's factors, consultant's factors, and external factors. Even though those problems come from stakeholders or other external factors, the project manager's jobs is still the need to tolerate and manage those factors smartly because anything that happens in the project is under the project manager's responsibility. The management approach has a significant relationship with the improvement performance of construction project performance (Agyekum-Mensah and Knight, 2017).

By referring to the challenging times that is experienced by project manager nowadays, it shows that many efforts from project manager are needed in order to ensure the project is not over scheduled. It indicates that the role and responsibility of project manager is very wide in ensuring the project can achieve the target in passing through various challenges in the nature of the construction project. The project manager plays the role as a project manager in planning, conducting and controlling (Sommerville at al., 2010) in an effort to compete with the challenging environment.

This is because project manager do not only manage the team, but also need to influence the team to achieve the project goal. On the other hand, project manager do not only control the project duration to be within schedule, but also need to identify and solve the rising matters that can influence the smooth flow of work that is a hindrance to the project schedule.

Usually, project manager should deal and react to many issues to satisfy the activities required, organization needs, team members need, and individual needs. Thus, project manager functions as the middle man between the strategies disciplines of the project and the project team members (PMI, 2013) in order to run a successful project. As mentioned by Sommerville et al. (2010) not implementing the role of a project manager successfully is the main cause for project delay. It is important that the project manager should take a role that can deal with the existing challenges that are required.

Moreover, reported by Shibani and Sukumar (2015) and Nguyen et al. (2004) competent or effective project manager is the most important critical success factor in construction projects. The top five critical success factors in construction project are an effective project manager, adequate funding until project completion, multidisciplinary/competent project team, commitment to project, and availability of resources (Nguyen et al., 2004). This study is to identify the critical success factors and agree that involvement of project manager in a project's success is important.

Moreover, to ensure that the role of the project manager has a suitable connection with the existing project surrounding, firstly Sommerville et al. (2010) suggest that the project manager needs extra skills, knowledge, abilities in an attempt to compete, and deal with unexpected situations, complex and dynamic market in the construction industry environment. Shibani and Sukumar (2015) and Hwang and Ng (2012) also agreed that project managers need to have knowledge areas and skills in order to be a competent project manager. It becomes compulsory for the project manager to gain various practical knowledge and skills in order to lead the project to become successful in achieving the project objective.

However, many obstacles will be experienced by the project manager himself or herself. The findings by Holt (2013) discusses about business failure in general. It was discovered that managerial position is the top generic failure agent (GFA) that contributes towards business failure. From the analysis, managerial factor contributes 45% in construction failure followed by financial, macroeconomic and company characteristics. In addition, the findings from the summary of literature sources that concentrate on construction management showed that managers are also included as the main agent that causes construction failure same as to financial with 37%. Next, followed by macroeconomic and construction characteristic (Holt, 2013). Normally, the biggest factor that causes the project failure has the biggest opportunity to make the project a success if that factor is managed carefully and improved dramatically. That is why the managerial role of an effective project manager in construction field is crucial to be improved in order to prevent the project construction from failure.

There are many studies that are conducted in order to define the characteristic of an effective project manager. Understanding behavioral characteristics, leading others, influencing others, conflict management, authentic behavior and culture awareness. All of these are the six skills that project manager need to be concerned as an effective project manager in industries like IT industry and construction industry (Fisher, 2011). Bredillet (2015) said that a good project manager is one who performs the project within schedule, within the project goals and fulfills the project manager’s role with the best way.

However, in order to become a good or competent project manager, there are many factors that are able to influence the project manager to become incompetent. Based on the analysis, lack of cooperation with others is the biggest barrier to be a competent project manager. This is because the project manager fails to influence others to cooperate on a shared project goal (Zhang et al., 2013). This problem requires the project manager to have knowledge in managing people. Therefore, Panas et al. (2014) said that to be a competent project manager, it is necessary for the project manager to have knowledge management and experience. Knowledge management is the main factor to be concerned when facing complexity in a project management environment (Ahern et al., 2013). That is because without a competent project manager, it is easier for a project to be delayed (Hwang and Ng, 2013).

Therefore, Project Management Body of Knowledge (PMBOK) by Project Management Institute (PMI) in its fourth edition introduced ten knowledge areas that provide guidelines for effective project management to manage a project successfully.

The ten knowledge areas are integration management, time management, cost management, quality management, scope management, human resource management, procurement management, communication management, risk management, and stakeholder management.

2.4 The Implementation of Project Management Body of Knowledge (PMBOK)

2.4.1 Project Management Methodologies

Project management has become the essential approach to ensure the project can be run smoothly. There is a need for manual guidance for project management methodologies as the best reference in project management field. Matos and Lopes (2013) state that large investment has been allocated to build and train the managers in the process to gain knowledge and skill that is required to conduct the project successfully.

In addition, many project management methodologies have already been established year after year. Each methodology has its own specialty compared with other methodologies. According to Charvat (2003) cited by Maryman (2011), the existing methodologies that have been developed and used until now are Agile, PMI, PRINCES@, SCRUM, Waterfall, and V-Methodology. The basic features that exist for each methodology are the planning stage, executing stage, and closure stage. Even the names that they use may be different.

Moreover, not all the methodologies are suitable and user-friendly to project management application. Normally, methodologies that are widely used by people are good and user-friendly. Based on Siegelaub (2004) and Wideman (2002) mentioned that the methodologies that are widely known and used frequently by project management all over the world are PMBOK by PMI and PRINCE2. Matos and Lopes (2013) and Karaman and Kurt (2015) also added that PMBOK by PMI and PRINCE2 are the most popular methodology among companies and organizations in project management field. Therefore, this study only compares between these two methodologies to show which is more appropriate to use in this study.

2.4.2 The Comparison Between PRINCE2 and PMBOK

PRINCE2 and PMBOK are considered as common project management methodologies that are mostly applied in project management areas (Matos and Lopes, 2013). In an effort to see the differences between both methodologies, Table 2.2 shows the comparison between PMBOK and PRINCE2.

Table 2.2 Comparison between PMBOK and PRINCE2

Items	PMBOK	PRINCE2
Project definition	Activities that are conducted as a temporary action to develop a special product, service, or result	The delivery of one or more business products through the management environment that is developed based on a specified business case
The application standard	International standard that is in coordination with ISO 21500	Structured method as a standard that is acknowledged in public and private sector
Describe the method	Use of description	Use perspective
The Project management processes	Initiating, planning, executing, controlling, and closing	Starting up, directing, initiating, planning, controlling a stage, managing product delivery, directing, and closing
Knowledge areas	Integration management, scope management, time management, quality management, cost management, risk management, communication management, human resources management, procurement management, and stakeholder management	Combined processes and components, change control, plan business case, quality configuration management controls, risk, combined processes and components, and organization
Sources	PMBOK (2013)	Matos and Lopes (2013)

Besides, PMBOK follows international standards that coordinates with ISO 21500 in order to develop a standard for project management practitioners and other project management profession standards. In addition, it is approved by American National Standard Institute (ANSI) as an American National Standard (ANS) (PMI, 2013). Because of that, PMBOK has been the project management standard in the United States, South Africa and Canada (Maryman, 2011). However, the PRINCE2 is using the structured method as a standard that is acknowledged in public and private sectors. PRINCE2 is used broadly as the project management standard in English government and in private sectors and mostly in UK private sectors (Matos and Lopes, 2013).

Moreover, in PMBOK, uses description to explain the processes that is involved and informs regarding the techniques, inputs, and outputs that are needed during each process (PMI, 2013). Otherwise, in PRINCE2, it uses a perspective to explain the ways the project management method that are needed to be arranged and implemented (Matos and Lopes, 2013).

The processes, which involve both PMBOK and PRINCE2 are different too. In PMBOK, it consists of five phases of processes, which are initiating, planning, executing, controlling, and closing. Whereas in PRINCE2 considers eight processes like starting up, directing, initiating, planning, controlling a stage, managing product delivery, directing, and closing (Matos and Lopes, 2013).

However, the parameter and the variables that are used in the PMBOK and PRINCE2 have several similarities. In PMBOK, the variables that are used are called knowledge areas. The ten knowledge areas that are involved in PMBOK are integration management, scope management, time management, quality management, cost management, cost management, risk management, communication management, human resources management, procurement management, and stakeholder management (PMI, 2013). In PRINCE2, the variables that are included are combined processes and components, change control, business plan cases, quality configuration management controls, risk, combined processes and components, and organization (Matos and Lopes, 2013). The similarities of the variables are integration, risk and quality.

Although, both methodologies have a few similarities but the difference are more dominant. Each of this methodology must have differences that make one from both project methodologies special and most suitable in project management methodology. Karaman and Kurt (2015) said that the PRINCE2 and PMBOK are the most popular project management methodologies.

Referring to the above comparison, PMBOK methodology is more accurate to be used compared to PRINCE2 methodology because PMBOK is recognized as a international standard, whereas PRINCE2 is recognized by public and private sector through structured method. Besides, PMBOK provides descriptive explanation for each process that involves the user's understanding but PRINCE2 uses the perspective explanation to explain the techniques implemented.

Moreover, the variables that are used in PMBOK are more detailed compared to PRINCES2 because PRINCE2 do not cover properly the certain variables, which are cost, scope, time, communication, human resource, procurement and stakeholder. The PRINCE2 methodology also covers those variables but it is not in detail.

According to a case study conducted by Matos and Lopes (2013) which aims to select the best project management methodology to be implemented, the project manager in software development have said that PMBOK methodology is the best project management practice compared to PRINCE2 methodology after having made an analysis and comparison between both methodologies. It is because PRINCE2 cannot fulfill some factors involved in managing people like giving motivation and managing team members. Besides that, PRINCE2 also failed to provide risk management flow and common planning tools like Gantt charts and critical part method (CPM). Moreover, based on Williams (2008) cited by Matos and Lopes (2013), PRINCE2 also do not deal with business management, cost control and value management.

On the other hand, the same study was also conducted by Maryman (2011) which aimed to identify the knowledge areas of project management that gives most impact towards project success in manufacturing. Information technology projects claim to use PMBOK as the project management methodology for the study. This decision was taken after conducting a research in PMBOK and PRINCE2 methodologies. The result shows that PMBOK is the project management methodology that was used broadly and accepted by many practitioners all over the world. Besides that, it also recognized as user-friendly method because the processes and items inside PMBOK provide brief explanation that help the users to understand easier. This results in the PMBOK being recognized as the better project methodology when compared to PRINCE2.

From the above explanation, it is described that PMBOK is the most suitable project management methodology compared to PRINCE2 to use for the project managers to manage the project in order to achieve a successful project. Therefore, this study uses PMBOK as the guidelines for the project manager to manage the project successfully.

However, even though the PMBOK is one that is great guidelines for project manager that provides a step-by-step guidance and it integrates those knowledge areas through project management process, but PMBOK is still difficult to be practiced by project manager. How can PMBOK guide project managers to effectively manage this project based on five different process groups, as well as with different areas of knowledge for each process activity? (Furlong and Al-Karaghouli, 2010). On the other hand, Zwikael (2009) cited by Maryman (2011) argue that the role of project managers are many, but to implement all the knowledge areas will take time, resources, and sometime the project manager himself does not have an idea about the knowledge areas of project management. Maybe because of these reasons, many of project managers tend to solve and manage the issue that exist in construction project by looking only in certain knowledge areas.

2.4.3 The Research on The Knowledge Areas in PMBOK

In PMBOK, each knowledge area has equal importance in most of the project, but not necessarily all the knowledge areas involved in the project (PMI, 2013). However, in previous research, some of them tried to solve project problems in an inaccurate manner. This is because they viewed knowledge areas one by one or see the knowledge areas separately. It seems that some knowledge areas are more important than other knowledge areas. According to Zulch (2014), communication is the foundation area for project management during managing the project. Project manager need to be good in communication because communication can affect the time, cost, safety, quality, and at the same time the scope of the project (Zulch, 2014).

In addition, Ochieng and Price (2010) also agreed that communication is very important in a project because effective communication can solve many problems like misunderstanding, missing in action, and client expectation. Communication enables the transfer of knowledge effectively. The main cause of conflict in construction comes from unsuccessful communication between parties. Conflict in construction does not come from allocation of risk, workmanship, quality performance, and delay, but it comes when communication is not used effectively (Mitkus and Mitkus, 2014).

Moreover, in other knowledge areas, people look at stakeholder management as the most important knowledge area that influences the performance of construction project. Yang et al. (2011), mentions that successful stakeholder management has significant contribution toward construction project. Therefore, project manager needs to focus on stakeholder development management. Li et al. (2012) elaborated that, many projects do not achieve the project objective when the stakeholder's concern are not fulfilled by the project manager. It is because stakeholder's concern can influence the public perception and affect the degree of conflict involved (Li et al., 2012).

Besides that, Mok et al., (2015) said that stakeholder has close interdependency between every phase in the project because stakeholder are related with unpredictable and uncertain activities. If the stakeholder encountered some problems, it will affect a certain phase of project and at the long term it may affect the overall project. Mok et al. (2015) suggested that decision making in project construction can be improved by the appraisal of stakeholder. It showed that stakeholder management has no less important knowledge areas in project management when compared with other knowledge areas.

However, project risk management is also part of knowledge areas that is important in project management of construction project. Mahamid (2011) said that risk has been taken as the high attention in construction because it will effect directly towards time and cost overrun. Jarkas and Haupt (2015) mentioned that construction is a risky field and is difficult to identify the risk but can only be identified when the project goes over budget and is over scheduled. Besides, through managing the risk, the project performance can be improved and also can affect the progress of projects. Serpella et al. (2014) said that many literatures show that risk management are elements that mostly affect project management performance and at the last, affect the projects' performance. Hwang et al. (2014) mentioned that risk management has positive correlation with achievement and improvement of small project construction performance in critical project success factors which are quality, cost and schedule.

Furthermore, human resource management is one of the knowledge areas that need to be more concerned. Without human resources the project does not have source to run the project and without managing human resources properly the project cannot be done effectively. Pournader et al. (2015) stated that human resources management should be the primary concern by project manager during ongoing the project. Human resource is merely the critical success factor organizing the project to become a success. Human resource management practice has positive relationship with organization performance in a way to achieve the project objective (Pournader et al., 2015).

Besides, Lai et al. (2011) mentioned that human resources practices can reduce the risk of accident in the project and not reducing accidents can prevent the project from being delayed. It is proven that human resources are the important asset in a project because among the activities of human resources it includes training and motivating workers. As mentioned by Tabassi (2012), training and motivating can improve the teamwork performance and increase the construction of project's efficiency.

At this point, in a holistic view, it seems that every knowledge area is necessary in the construction of project management field. However, most of the researchers look the knowledge areas one by one or separately and do not have interdependency and interrelationship between them. As discussed in Peraphan et al. (2017), the greatest way to make an effective problem solving in the dynamic complexity of projects is a deeper understanding about the interrelationship within the projection systems.

Therefore, looking at only one knowledge area or looking at the knowledge areas separately, is not sufficient enough to understand the causal relationship causing the problem that arise. As well as inadequate in making a decision or plan will affect other knowledge areas in the project and end up affecting the overall project. Understanding the interrelationship between several factors can help the decision making process faster and more strategic in planning (Iannone et al, 2015). For that reason, this study is aimed to identify the interrelationship and interdependency between different knowledge areas in PMBOK focusing in a construction project.

The purpose to identify the interconnectivity and interrelationship between different knowledge areas in PMBOK is to ensure the project manager does not look at the knowledge areas that are related separately or one by one, during managing or solving the project issues. Normally people can accept that some knowledge areas have interconnectivity and interrelationship between them. As we know, every event or incident must have other factors or variables that have close relationship that allow the event or incident to happen.

As stated by Lai et al. (2011) that project over schedule may happen because of accidents in construction. Accident in construction is caused by carelessness of risk management and risk management can be reduced by practicing effective human resource management (Lai et al., 2011). In short, increase in human resource management will increase the risk management and increase in risk management will reduce the accident that could happen. The reducing numbers of accidents event will reduce the project over schedule from happening. Those factors or variables can be a lot or little and affect directly or indirectly influencing the event. Therefore, in order to solve the project problem efficiently, factors or knowledge areas that can influence the project performance much better if it can be looked fairly, without focusing only on a certain part.

Looking at different knowledge areas one by one does not ensure the result of study that comes out is accurate. Shehu (2014) claims that the reason for the construction project cost overrun are because procurement and quality factors are involved directly in a project. It shows that, the cost overrun in construction project is happening not due to the lack of cost management itself but because of the involvement of procurement management and quality management. This proves that the different knowledge areas are interconnected and there is interrelated between one and another in order to solve the problem. It is more secured to look at the knowledge areas not separately in the way to define the accurate results of study.

Besides that, the need to see the knowledge areas are not as separate is because it can be easier for the project manager to look at those knowledge areas in a big picture in order to plan some strategies for the project in an effort to achieve the project goal within various challenges. It is like the triple constraint concept. Normally triple constraint consists of three elements, which are cost, time, and scope. Stated by Cuellar (2010) the normal concept that is currently used in academic areas and practical areas about project success is based on 'triple constraint', which are project scope, project time, and project cost. The assessment to know whether the project is successful or not depends on the circumstances of project cost, time, and scope. If we want to reduce the time, we need to reduce the scope and increase the cost (Catanio et al., 2013). In order to solve the project delay, commonly we need to increase the budget and reduce the scope. Triple constraints is one of the methods that can help the project manager to plan projects' strategies in general because those knowledge areas are looked at not separately.

However, in the way to solve the certain issues in the project, at times project leader tend to focus more on the three knowledge areas in triple constraint, only because these knowledge areas are the crucial knowledge in order to manage the project effectively. It makes the project leader overlook other knowledge areas that have close interrelationship and influence with the project performance. Different project has different approaches (Andersen, 2016). This situation can cause the project leader to be biased when making decisions.

Moreover, the project manager cannot look at the cause and effect of the project issue clearer. The issue is not clear because the project manager does not know the link and the interrelationship between other knowledge areas that are involved. The project manager cannot take into account, if changes happen in one knowledge areas or what will happen to other knowledge areas. Schedule pressure in project manager's work sometime makes the project manager has no time to review a decision that is made (Sheffield et al., 2012). It requires the project manager to look into a problem partly, not in the big picture. The project manager needs to be middleman to all parties in the project (Zulch, 2014), which is necessary to know all the knowledge areas as a whole and the interrelationship between those knowledge.

In addition, if any decision that is made by project manager without considering other knowledge areas, the outcome from that decision is possible to become worse maybe not in the short term but in the long term. Maybe the decision could solve certain problem at that time, but effect from that decision will appear in the future because the project manager did solve the problem partly without taking into account the cause and effect after the decision has been taken. Sheffield et al. (2012) stated decision making that is made by a leader mostly has some bias because they take it easy in making decisions and the situation often changes.

In other circumstances, the effect of looking at the knowledge areas separately can cause the project manager to delay or take a long time to make a decision. It is maybe because the project manager is not clear or cannot imagine what will happen if the decision is taken, which leads the project manager to become not confident in making decisions. That situation causes the decision that is made to be delayed or takes a long time. It will give bad impact on the project manager and the project itself, as it is normal for the project manager to give the feedback or make decision on time (Kanapeckiene, 2010). According to Sheffield et al. (2012) reported most of project managers tend not to use a system that can understand dynamic thinking because they are trapped into linear thinking patterns.

2.5 The Application of System Dynamics in Construction Management

2.5.1 The Description of System Dynamics

Changes keep happening all the time (Iannone et al., 2015). In addition, construction project is known by its uncertainty, risk, complexity, and dynamics environment. No one has time, energy, knowledge, or experience to know about everything in a short time. To solve this, a project leader or project manager needs to have tools or systems that can be used to see the interdependency and interrelationship between different knowledge areas in a big picture within a dynamic and complex system. Therefore, there is a need of a system or tool that can help project managers to solve the problem in a holistic view like system dynamics.

System dynamic is the system that is introduced by Forrester in the late 1950s at the Massachusetts Institute of Technology (Li, et al., 2018). This system is developed to model a complex system with a holistic view which includes the feedback processes to see the relationship between the variables (Tegegne, et al., 2016). This system merges all the information that is required, including primary data and secondary data through computer simulation in order to see the overall behavior system clearly (Li, et al., 2018). Besides that, the basic instrument to develop the system dynamics is through the combination between traditional management of social systems (accurate data), feedback theory, and computer simulation (Forrester, 1976). Based on Figure 2.3, it demonstrates that system dynamics can improve the traditional management without throwing away the traditional function totally.

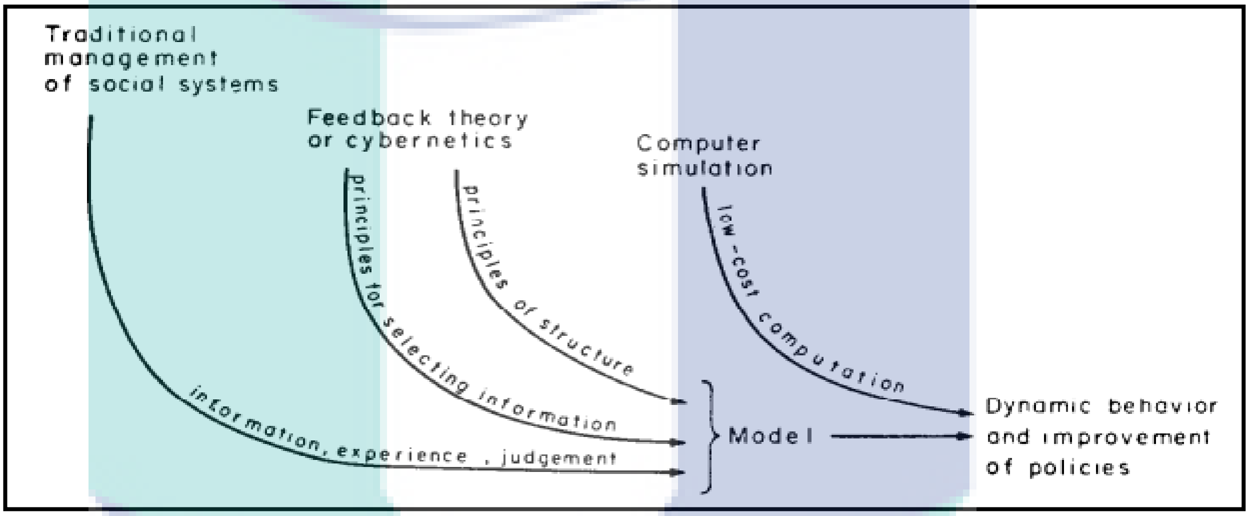


Figure 2.3 Background of system dynamics modelling
Source: Forrester (1976)

Many traditional tools have been developed in order to help manager to ensure the project can be run within schedule, cost, and project's requirement such as work break down structure, critical parts methods, and gantt charts. Through this traditional tool, the result that comes out is accurate but it runs individually (Sonawane, 2004) and the tool does not fully support the result (Lee, et al., 2015). The traditional technique function is static through one way (Sonawane, 2004). As we know, project management in construction is involved with complex, challenges, and dynamic in project nature. These situations lead to the project manager to compulsorily use a dynamic approach when managing the construction project to improve the project performance. Therefore, it is necessary for the traditional approach to shift or merge with a powerful approach that can see the project from an overall picture like system dynamics.

Moreover, many research conducted by researchers uses the system dynamic to improve the existing traditional method. Ambroz and Alda (2010) claim that application of system dynamics is aimed to identify and prove the cases when the management model used by the organization has its limitation. Based on their first case study, system dynamics is used to replace the old model of pharmaceutical industry that can improve the management process for a decision-making. The previous traditional method "analogue approach" is built to focus on certain factors and it cannot cope with the dynamic factors.

Therefore, it needs a suitable system that can run in high complexity like system dynamic. As the result, stock and flow of system dynamics can show a better understanding of the system and the common quality assumption and throw away the complicated equation. Using system dynamics is easier for clients to understand the flow and easier for the owner to retest the model to increase the confidence level of the result and easily detect the cause and effect of each variable when the changes happen (Ambroz and Alda, 2010). Besides, the common cause of occurrence on the cost overrun in Malaysia's construction project is due to less of survey on the industry environment for the 'cause and effect' level (Shehu, 2014) because the ability to see the cause and effect can reduce the severity of cost overrun's impact. So, system dynamics is suitable to be used in an effort to improve the existing traditional method and to increase the confidence level during decision-making.

In addition, the second case study shows that, system dynamics is used to develop a big framework through integration of all factors in manufacturing sector (Ambroz and Alda, 2010). This case is about the management in manufacturing sector that uses the exact management model from other companies that is unsuitable to adopt with other management model into an organization before checking carefully the suitability and the effectiveness with the current organization. At first, the management use of "conversion-probability tree" as the method to define the suitable model of management (Ambroz and Alda, 2010).

However, this method used is inaccurate of estimation and do not have specific systems to test the accuracy of the result. The existence of repetitive problem is due to the use of repetitive solution to solve the same problem (Kelly et al., 2013). Therefore, in this case the use of system dynamics as the method to integrate the various factors in a simulation system was used to test the impact and the causality between the various factors. As the result, system dynamics showed the quantitative data of the effect between factors clearly. On the other hand, system dynamics also interprets the profitability aspect that can help the management to make a confident decision-making when changes happen (Ambroz and Alda, 2010).

As a conclusion, system dynamics is a system that is suitable in order to help the management to make a decision in high level of confidence compared to the use of traditional method. It can also help in developing the strategy by integrating the holistic variables in the system and constructing the interdependency between those variables clearly.

2.5.2 A System Dynamics in Building a Strategic Model

Among the widely used methods based on modelling and simulation, Model Based Aggregator, Discrete Event Simulation and System Dynamics are the most used (Saavedra et al., 2018). However, System Dynamics is known as one of simulation methods that is used by various system dynamics practitioners because of its ability to cope with complex system, modelling the interrelationship between sub-systems in order to understand the system behaviour, and to help in decision making (Saavedra et al, 2018).

One of the main function of simulation system is to make an estimation. Chou (2011) reported that project estimation could be divided into two parts that are probabilistic approach and deterministic approach. Probabilistic approach is more on operational system because this approach can run when some information is collected whereas deterministic approach is more on strategic system because deterministic needs detailed estimation of the wider factors. Deterministic is more suitable for estimating strategic problem (Chou, 2011).

On the other hand, estimation procedure is commonly valid in conducting single-value estimation or single purpose through the secondary data or primary data collection (Chou, 2010). Repetitive in running the simulation model can increase the confidence level and the accuracy for the estimation result. Frequent assessment can help the parties to realize the strength and the weaknesses of the relationship between various factors that can lead to project success. As the result, the parties can make a prediction for any effort as the way to solve the problem in project performance (Meng, 2012).

According to Tako and Robinson (2010), two of the most robust simulation approaches commonly compared are Discrete Event Simulation and System Dynamics. These two methods are often compared and mixed (Morgan et al., 2017). However, not all simulation system is suitable to construct a strategic model. Based on Table 2.3, Moradi et al. (2015) explained that, each simulation system has its own purpose, specializes and main function. Discrete Event Simulation is also one of the simulation techniques, however this simulation technique is more suitable for solving problem in operational problem (Jovanoski et al., 2013). This is because the way this system is running is through analytic system and not holistic system (Morgan et al, 2017). Analytical system cannot cater for the complex and overall factors in the system.

Vice versa System Dynamics is a system that can run in holistic approach (Morgan et al, 2017). Moreover, system dynamics is also more suitable to solve the problem that is related with strategic issue because system dynamics can see the overall of the factors that are related (Tako and Robinson, 2010). Based on Table 2.3, the purpose of system dynamics is strategic planning and managing the decision making. Therefore, in order to construct a strategic model, system dynamics is most suitable to be used.

Table 2.3 The difference between system dynamics and discrete event simulation methods

Criteria	**System Dynamics**	**Discrete Event Simulation**
Sources	Forrester (1976) and Moradi et al. (2015)	Moradi et al. (2015)
Problem scope	Strategic	Operational
Control parameter	Rate of flow	Time of turn

Model type	Qualitative or Quantitative	Quantitative
Nature of model	Deterministic(Holistic)	Stochastic(Probabilistic)
Model components	Stock and flows	Queues, activities, and processes
Purpose	Suitable for strategic planning and develops the relationship between that factors that involve for managerial decision-making	The decision taking through optimize, accurate estimation, and compare the result with other cases

2.5.3 System Dynamics in Construction Management

Nowadays, the complex environment of projects in every field especially in construction project is very challenging for project management. It is because something that is related with dynamic characteristics, is continually changing (Mawdesley and Al-Jibouri, 2009). Changes that frequently happen, needs to be managed properly and at the same time, it can affect the project performance mostly in terms of project time. Therefore, system dynamics simulation is developed in order to face the challenging project environments recently.

The functioning of system dynamics simulation is developed to cater a purpose. System dynamics is a function to study a complex system (Mawdesley and Al-Jibouri, 2009). Moradi et al. (2015) said that system dynamics simulation is the best tool and methodology to solve the problem related to uncertainty, complexity, and integrates various factors. The system dynamics methodology also functions to simulate the decision-making process under changing conditions (Deniz and Zhu, 2016). The system dynamics model is used as a causal loop diagram to understand major feedback process (Ding et al., 2016), then the change that happen can be understood (Mawdesley and Al-Jibouri, 2009).

System dynamics simulation is very useful and is already used in various different fields not only in construction project but also within economic, business, ecologies, social, and in agriculture researches (Ding et al., 2016). Besides that, the contribution of system dynamics simulation is very powerful to solve various problems in various fields for example, system dynamics is used to develop strategicies in manufacturing process capabilities, to define the factor to improve the manufacturing capabilities (Grobler, 2010), system dynamics is also used to develop a model for Total

Quality Management (TQM) in automobile manufacturing sector, for defining the quality performance (Khanna et al., 2003) and system dynamics's model is developed to understand the quality performance in health-care sector (Jankuj and Voracek, 2015). In addition, system dynamics is also used to assess the financial situation in the company (Qureshi, 2007), and certainly to model the system dynamics to manipulate the business model situation itself (Hajiheydari and Zarei, 2013).

In continuity, the construction projects are also known for its complex and dynamics of project environment. Many studies use system dynamics simulation in order to solve certain issues in the construction project due as the capability of system dynamics simulation in functioning in a complex project. Some of the studies in construction project that uses system dynamics simulation as mentioned by Mawdesley and Al-Jibouri (2009) had stated that they use system dynamics simulation to reduce productivity in the project construction. It also causes the development to be slower, which has led to the need for use the system dynamics to model construction productivity in order to improve the productivity of construction project.

Besides, Mohamed and Chinda (2011), claimed that use of system dynamics simulation is to identify, the interaction among influencing factors on practicing construction safety culture and also the impact toward the organization goal against times. In addition, Hajdasz, (2015) stated the use of system dynamics is to understand the repetitive construction project within complex construction environment and as a decision-making tool to help in making decision in execution stages of construction project.

Recent studies stated that use of system dynamics simulation in a construction project are usefull. Deniz and Zhu, (2016) used system dynamics in construction project as the purpose to understand the impact of various project conditions toward the decision-making that are taken by construction professionals. Then Ding et al. (2016) also used system dynamics model to manage the reduction in reducing construction waste and to simulate the benefits in environment condition within sorting behaviors. Some of the users who are interested in applying system dynamics simulation and project managers, because it is useful to help project managers in developing strategic model to improve the project performance. Stated by Mawdesley and Al-Jibouri (2009) the application of system dynamics in project management is already in use a long time ago because the first application of system dynamics in project management was developed by Roberts in the year 1964.

Most of the studies that use system dynamics are to increase productivity, make strategies, evaluate organizational performance, assist in decision making and more. But there is still no study that use knowledge areas in PMBOK as their main references and uses system dynamics in the study. Therefore, this study uses system dynamics as the method and tool to understand the interrelationship and interconnectivities between different knowledge areas of PMBOK in a construction project. Then, to develop the suggestion strategy by system dynamics model for improving the construction project in terms of project time.

2.6 Summary

Project Management Body of Knowledge (PMBOK) is available to project manager within ten knowledge areas, that is mostly faced by project manager and the need to manage the project properly. Those knowledge areas are the common guidelines for project management that is provided by Project Management Institute (PMI). In order to solve the project delay, the project manager needs to look all knowledge areas that are related not within one by one or separately but to look at it in a holistic view. It is because some of those knowledge areas have interconnectivity and interrelationship between them, which project manager need to understand. Besides that, it is easier for the project manager to look in a bigger view in order to plan the project strategies especially when the system dynamic simulation is used. Because of that, the project manager can confidently make decisions and improve project performance.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This methodology chapter describes about the method that is used in this study. This chapter is divided into several sub-topics, which begins with the research process flow that discusses about how this study is conducted. Followed by the steps of system dynamics processes starting from the first step until the fifth step. Firstly, it descusses about problem articulation together with sub topics of data collection, interview, and document content analysis. Secondly, dynamics hypothesis with its‟ sub topics of causal loops diagram and feedback process.

The next step is the formulation of a simulation model and its‟ sub topic is on building block of system dynamics. The fourth and fifth steps are testing the model and policy formulation and evaluation. After the discussion about system dynamics modeling process is completed, it continues with a discussion of the system dynamics software and ends with a summary of this chapter.

3.2 Research Flow

The research flow is the part that shows how this study is conducted. The flow for this research generally follows the standard processes for constructing the System Dynamics model. The process of modeling this System Dynamic has already been explained clearly by Sterman (2000). This System Dynamics modeling process is used broadly as the reference by various researchers that have applied the system dynamic in their research (Fan et al., 2018). The process offers guidance to model this system correctly from the start until the end.

Based on Figure 3.1, system dynamics modeling process can be divided into five processes. The processes involved are problem articulation, dynamics hypothesis, formulation, testing, and policy formulation & evaluation. These processes are the standard procedures to develop a System Dynamics model (Fan et al, 2018). Each process runs in sequence and should be understood for a clear understanding how to construct the model (Sterman, 2000). Hence, this system dynamics modeling process is used as a guidance for the research process or research flow in this study.

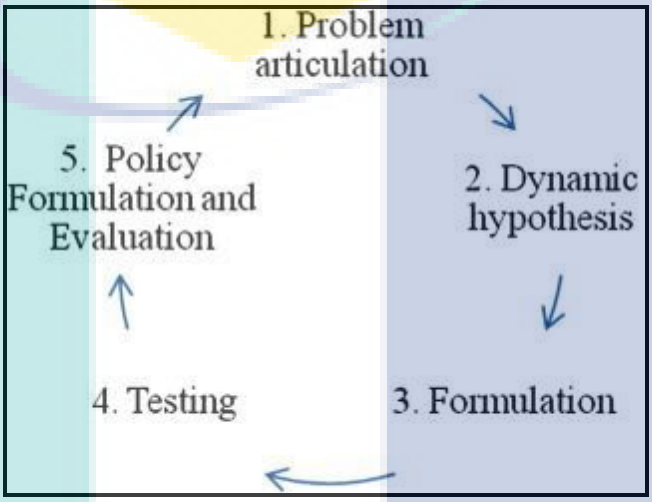


Figure 3.1 System dynamics modelling process

Source: Sterman (2000)

3.3 Step 1: Problem Articulation

The process starts with identifying the problem and the objective to construct a boundary, also about the scope of study that will be focused on. From the scope of the study, the problem that is discovered should be narrowed to the scope of study. In this level, factors in each knowledge area of project management in PMBOK that can influence the project performance are identified (Chapter 4). The data collection is from primary and secondary data such as interview session, observation, company historical data, magazine, newspaper and previous studies.

3.3.1 Data Collection

This study is conducted as a case study as to collect quantitative data for developing a system dynamic simulation model. The case study methodology helps the researchers easier to understand the various variables in a smaller scope, which in turn will help to understand the interconnectivity and interrelationship between different knowledge areas in PMBOK during construction project. Besides that, the case study also provides a contemporary event within its real-life context. The case study should include various activities as variables that are mutually connected, that will be used in the process to develop the system dynamics simulation model. The suitable way to collect the data for this study are by interview and document analysis.

3.3.2 Interview

In order to develop the system dynamic simulation model, an in depth understanding of the construction project process case study in needed. Hence, several interview sessions with experts are conducted. Some specific questions were constructed and then modified during the interview based on the ability of respondents to answer the questions. The selected case study is taken from one of the residential housing construction projects from a construction company in Kuantan, Pahang. The reasons for selecting the case study of this construction company are, first this company was easier to deal in order to get the related information and secondly, this company has over 20 years" experience in the project management field, and has built several residential housing construction projects.

Interview method is the suitable way in understanding the case study because most of the case studies approach is about a human behavior (Ullah, 2012). The individual who is suitable to be a respondent in this study is a person who works in project management field. Several interviews were conducted with this person who is in charge in the Project Management Department. The position of this person is as an assistant project manager. This person is responsible as a project manager for a residential housing construction project in Mukim Kuala Kuantan, Daerah Kuantan, Pahang Darul Makmur.

The data that was collected was about the process of pre-construction stage in a residential housing construction project. It is because this company is a reputable property developer company. This company is involved in the pre-construction project directly, but during the construction project this company sub contracted to other companies to conduct the construction process, but they still monitor that company. It is suitable enough to answer the objectives of this study.

During the interview, the researcher asked the respondents about the problems that occurred in the project related to the project management field. After the researcher had understood the problem, the researcher than asks the respondents' understanding and opinions related to the importance of knowledge field in PMBOK during the construction project

Respondent answered the questions based on a particular understanding that is actually related and included in the scope of the knowledge areas in PMBOK. This informative response is important for the study, because the information of what respondent said provides the researcher a valuable information in order to develop a practical system dynamics model. The duration of the interviews was 30-45 minutes.

The researcher had set some interview sessions from April 2015 until May 2016 with the respondent. Table 3.1 is presents the interview schedule for collecting the data and the main points that were discussed during the interview sessions. Based on the Table 3.1, the discussion during the interview sessions were divided into three parts. The first part was conducted to have an understanding about the study and collection of the data required. After that, there was a big time gap between the first and the second parts. During that time, the researcher conducted analysis and developed the causal loop model.

After the causal loop model was completed, then it was shown to the project manager to validate the model as the second part of the interview session. If the project manager had approved the causal loop model, the researcher moved to the next step as to develop a stock and flow diagram. After the stock and flow diagram was completed, then it was presented to the project manager again to validate the diagram. The validation from the project manager was quite simple, the managers understand the process of the system dynamics model developed based on the case study, answer the problem, and agree with the model developed. The verification of the model will be explained in the next chapter.

Table 3.1 Schedule of interviews and the main points of the interview discussion

Date	Point of discussion
April 2015 – May 2015	- An explanation about what this study is about, why this study is conducted and what will happen with the findings from this study. - Select one of the case study that is suitable to be implemented in this study - Identify the activities that are related to developing a system dynamics model
August 2015 – September 2015	- Show the causal loop diagram that is developed for this case study to be validated by project manager (one of the requirements to develop the system dynamics model) - Provide understanding to the project manager about that causal loop diagram - Need for some modification to the causal loop diagram
February 2016 – May 206	- Show the stock and flow diagram that is developed for this case study to be validated by project manager (one of the requirements to develop the system dynamics model) - Provide understanding to the project manager about that stock and flow diagram - Need for some modifications to the stock and flow diagram - Define suggestion strategy for system dynamics model

3.3.3 Document Content Analysis

The process for analysis of the document is based on the written documents that are gained during the interview session. Through the interview session, it helps the researchers to understand the relevant document clearly (Boateng, 2014).The written document about the historical data of pre-construction project in the residential housing project were provided by the case study in a pre-construction project. The valuable data consisted of:

1. The number of the activities that are involved in the pre-construction project stage

2. The number of processes that are involved during the pre-construction stage, which are preliminary process, plan approval process, and construction tender process

3. The number of activities in preliminary process

4. The number of activities in plan approval process

5. The number of activities in construction tender process

6. The schedule time for each activity to be completed in preliminary process
7. The schedule time for each activity to be completed in plan approval process
8. The schedule time for each activity to be completed in construction tender process
9. The actual time for each activity completed in preliminary process
10. The actual time for each activity completed in plan approval process
11. The actual time for each activity completed in construction tender process

Based on the written document data, the data is gained from quantitative data. It will help in the process to develop a system dynamics model and run the simulation model. The written document of the historical data for the processes that is required in the pre-construction stage is exhibited in Appendix A, B, and C.

3.4 Step 2: Dynamic Hypothesis

The next step is the process to develop the theory of system thinking through causal loop diagrams. To achieve the admissible of system boundaries, the problem articulated need to be related with the research objective as to define the important factor whether to include or exclude in the causal loop diagram. The first objective will be answered at this level, which is to identify the interconnectivity and interrelationship between different knowledge areas in PMBOK. This study will focus on a construction project. The causal loop diagram needs to explain the causal relationship (cause and effect).

It shows how the change in one knowledge area can affect other knowledge areas. Then, the causal loop diagram translates the interconnected between those knowledge areas from implicit into explicit through a diagram. The components of system dynamics approach that was used at this phase are causal loop diagram with the feedback process.

3.4.1 Causal Loop Diagram

To The causal loop diagram is one of the important parts beyond the development of system of dynamics model. After the problem statement of the study is identified, the dynamics hypothesis will be developed based on the objective of the study using the causal loop diagram. The causal loop diagram is also known as „influence diagram" (Sonawane, 2004). That is because the causal loop diagram is a tool that can help to explain the cause and effect relationship between different variables that are involved in the particular problem of system using the system thinking.

This diagram can provide a visual structure about the interrelationship of the factors to show the patterns of change that happen clearly rather than static cause and effect (Chunyan, 2006). The factors that are constructed during causal loop diagram can be taken into account as qualitative factors or quantitative factors. According Chuang (2011) stated that causal loop diagram is like a map that has closed loop after having linked to some of the individual variables that have a relationship between those variables.

3.4.2 Feedback Process

In a causal loop diagram, normally it has two feedback loop processes that are reinforcing feedback and balancing feedback. Reinforcing feedback loop is also called as a positive feedback loop and balancing or opposite feedback can also be called as a negative feedback loop (Chunyan, 2006).

Positive feedback loop operates generally in the same flow of feedback, whether growing action or a decline action. The plus or minus sign at the arrow indicates the positive or negative influence of the preceding factors towards the next factor (Sonawane, 2004). For example, as the Figure 3.2 showed, an increase in preparing project plans, increases the completion pre computation plan, and increases approval of MPK. However, when approval of MPK increases, screening and works error also increases, then it causes the preparation of project plans to increase back. The process is continuously running. The R alphabet represents the reinforcing or positive feedback loop. However, the positive feedback loop has high tendency to interfere with the system because the rates of the flow always increase or decreases.

Therefore, balancing loop is needed. It functions to rebalance the behavior system. From Figure 3.2, shows the example of the balancing feedback loop. For balancing feedback loop, an increase in approval of MPK, increases screening, and increases rework. If the rework increases, then work error becomes decreased. After the work error decreases the approval of MPK increases. When the sign at the starting point is different with the sign at the end of the loop, that means, the loop is a balancing loop. The variable in the box is the objective that want to achieve in these loops. Through the balancing feedback loop, the goal of these loops can be achieved. The function of balancing loop is to minimize the gap, define the goal and act as a self-correcting. The B alphabet represents the balancing or negative feedback loop.

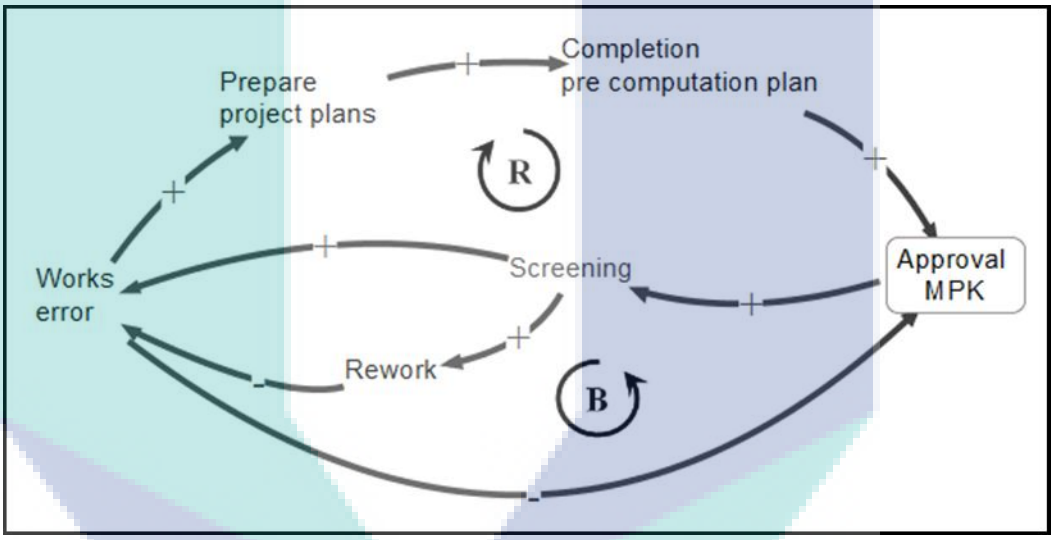


Figure 3.2 Feedback loops

3.5 Step 3: Formulation of A Simulation Model

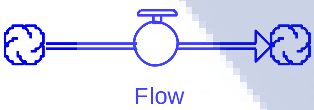
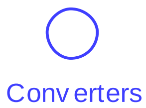
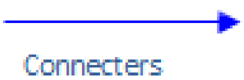
After the causal loop has already been constructed, then translated into stock and flow diagram, then only the second objective of this study can be answered. The second objective is to develop dynamics model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK. The stock and flow diagram will be modeled using iThink software. The stock and flow diagram should be linked with the feedback relationships between all the variables and include fully specified equation that can be measured to run the simulation test. At this stage, the model is run using the data collected. All this is presented in the Chapter 5. In this chapter, it explains the building blocks of system dynamics, which is the component that needs to create the stock and flow diagram correctly.

3.5.1 Building Blocks of System Dynamics

The building blocks of system dynamics are the items in the system that is needed in order to construct and run the system dynamics simulation. All these items are necessary to enable the inputs to be transferred from the causal loop diagram into system dynamics. It is important because the causal loop diagram does not contain enough information to run the simulation model (Burns, 2001). Beside that, not all the input in causal loop diagram need to be transferred into the system dynamic model, it is because the causal loop diagram consists with some assumption that cannot be calculated (Burns, 2001).

Table 3.2 shows four entities that is used to build a clearer understanding about the building block of the system dynamics which are stock, flow, converters, and connecters. It also includes an explanation about the function for each as described below.

Table 3.2 Building block of system dynamics

Symbol	Name	Function
	Stock	Stock's function as accumulation. They collect whatever data that flows into them and after that flow-flush whatever data that's not required of them.
	Flow	The job of flow is to fill and drain accumulations. It is an intermediary between the stocks and converter. The flow can control the amount of data or information that enter the flow or come out of the flow.
	Converters	The converter serves a helpful role in the software because it can help to change the complex flow equation into the simpler flow equation and easier for the user to understand the model.
	Connecters	The job of the connector is to connect the elements inside the model.

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The building block of system dynamics can be easily be understood through the explanation from the bathtub illustration in Figure 3.3. The interrelationships between the factors can be reflected by the stock and flow diagram that is represented by the pipe and the bathtub. It is because any-incoming data will enter the flow first. After that, the converter on the flow will control the amount of the information that will enter into stock or drain out from the stock. The stock will accumulate all the information entered and drain out the information through the next flow (Bacioiu, 2012). Similar as the bathtub application with the pipe; where the pipe represents the incoming water and the bathtub as the place to gather all the water. The pipe can control the incoming water and the outlet can control the outgoing of the water.

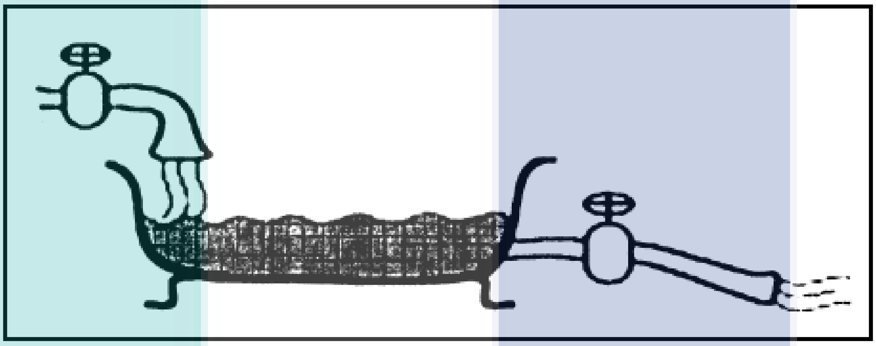

Figure 3.3 Bathtub application as the basic stock and flow function
Source: Sullivan (2013)

3.6 Step 4: Testing The Model

In this fourth step, the model will be tested through validity test. This test is to make sure this model is built correctly and work correctly.

3.6.1 Validation Test

The simulation behaviour model will run through several validation tests to ensure the model that is developed is valid. In this study, it presented three tests on the model structure. Firstly is face validity, which is to ensure the model that is developed is right and agreed by the client. The second is an extreme condition test. This extreme condition test was carried out during conducting the simulation process. This model tested under extreme conditions of parameter to discover the disability in the model structure and improve the disability until the model can run correctly and logically.

The last is the simulated behavior of the model is compared with the actual behavior in the real system. It is to validate the development of the model, by comparing the output of the simulation model with the actual output. Only then the model is considered valid. A detailed explanation on the validation test is conducted in Chapter 5.

3.7 Step 5: Policy Formulation and Evaluation

In this last step, the third objective of the study will be answered. The third objective is to make recommendation of strategy implication based on the interconnectivity and interrelationship between project management knowledge areas. Once the confidence level of structure and model behavior is achieved, which is the interconnectivity and interrelationship between knowledge areas modeled, validated and approved, the developer and policy analyzed can be taken for improvement in different strategies. This is the development and analysis stages of management strategy. It is explained in detail in Chapter 5.

3.8 System Dynamics Software

System dynamics software needs to be used in this simulation study. However, there are many types of system dynamics software in the market. According Sonawana (2004), system dynamics software that is mostly used by many people are STELLA/iThink, POWERSIM, and VENSIM. However, this study uses iThink software. It is because, this software is already used within construction field to investigate the feedback cause among enablers of construction safety culture in order to see the potential impact of each enabler toward organizational safety goals (Mohamed and Chida, 2011).

Beside that, Mohamed and Chida (2011) also state that iThink software is user friendly by providing guidelines for equation formulation. iThink software also was implemented by Chritamara et al. (2002) who studied about integration between critical parties in construction project in order to understand the relationship among those. This software is suitable for analyzing the interrelationship of the various processes in real-life construction project (Wan et al., 2013). It showed that this software is suitable to be used in construction project and to understand the different knowledge areas in project management.

3.9 Summary

The system dynamics is the method that is used in this research to answer the objectives of the study. The process starts with identifying the problem area from the preliminary information. The dynamic hypothesis is formulated, which is to define the interrelationship and interdependency between different knowledge areas in PMBOK through causal loop diagram. After that, the simulation model is constructed by converting the causal loop diagram into the stock and flow diagram. The information that enters the stock and flow diagram shall be adjusted according to the suitableness with the stock and flow diagram and then the model is tested. The model is tested repeatedly to achieve the validation of the result between the model and the actual data. Lastly, after the model is validated, the model can be used and undergo the evaluation to be used in different strategies for any improvement.

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CHAPTER 4

MODEL CONSTRUCTION

4.1 Introduction

Construction projects are hard to be managed due the reason of dynamics, complexity, and having a nonlinear relationship. As a result of that, a system dynamics model have been used many times as an effective tool to analyze dynamics and complex situations for both academic and practical purposes as mentioned in Chapter 2. In Chapter 3, it explained about the method that is used in this study, which is a system dynamics simulation. According to Sterman (2000), there are five processes required to develop a system dynamics model, namely problem articulation, dynamics, formulation, testing, and policy formulation and evaluation.

This chapter discusses in detail about the processes to develop a system dynamic simulation model. However, in this chapter, it will focus on the discussion on certain processes in the system dynamics processes, which are problems on articulation and the dynamics hypothesis. The rest will be discussed in the next chapter. This chapter will be divided into several sub topics, which begins with an introduction followed by understanding of the mental model in identifing problems and then the creation of the causal loop diagram to develop the dynamics hypothesis. Lastly, this chapter ends with a conclusion.

4.2 Understanding The Mental Model

The primary step in developing a system dynamics model is problem articulation or problem identification. Identifying the problem is very important to determine what the problem that will be studied and how it will be solved in this study. To do that, a mental model is required to understand the general sequence of events and the variables that are involved in the project that causes problems to arise. From this model, the researcher can know the situation of the variables and the problem clearer

Through the interview session with the project manager, the mental model of the pre construction project stage are captured as in Figure 4.1. The mental model that is shown in Figure 4.1 provides the flow of the pre construction project activities and the processes that are involved in pre construction project stage. The pre construction project stage is divided into three main groups of processes, which begin with preliminary process, followed by an approval plan process, and then construction tender process. The main activities in each process that are related in pre-construction stage are also shown in the Figure 4.1.

Preliminary process is the first processes in pre-construction project. The preliminary process starts with the activities that are involved with conducting site visit to define the suitable land for carrying out the planning of housing construction project on that land. The site visit activity was conducted in various areas to select and get the best land. After that, land survey activity took place to study the clients demand and the demand for housing design that was appropriate for the land. If the land is suitable, only then the land is purchased.

Next, after purchasing the land, planning the project on the land was conducted, followed by preparing paper work of the project in order to get the management approval. If the approval is achieved, the next process can be initiated. However, if the approval is not achieved, the preliminary process has to be repeated and the paperwork should be improved until the approval management is achieved.

After the preliminary process is done, the process for plan approval can commence. The first activity is preparing a pre computation plan until Majlis Perbandaran Kuantan (MPK)'s approval is received from that plan. If not, the plan approval process should be on hold. After the pre computation plan has received the MPK's approval, the next activity can proceed. The same process must be passed for the building plan and infrastructure plan to get approval from MPK. In order to get the MPK's approval it will take time to construct the plans, send the plans to MPK, make some correction, and get approval again from MPK. After all the activities are done, this plan approval process is completed.

The last process in the pre-construction project stage is tender process. Preparation of tender by the quantity surveyor is the first activity on receiving a tender award. After the tender has been prepared and accepted by management, then the tender can be advertised widely, to call for the interested contractors and tender offer is closed at the end of the allocated time. Then, management screens the list of contractors based on project specification. The best contractors that fulfill the requirement will receive the tender award.

Although the processes look simple, but in the pre construction project stage, there are times the construction project stage cannot meet the time scheduled. It is likely caused by one of the processes in pre construction project stage or other processes that may be involved. Because of that, understanding the feedback causal between the activities or variables is needed in order to know how the pre construction project stage could run over schedule from the time allocated.

Nevertheless, the mental model could not capture the interrelationship between different variables and also understand the feedback causal clearly. Besides, the problem that happen might be from a complex relationship between different variables. However the mental model only can present the relationship between different variables within a liner relationship. Therefore, it leads to the need for developing a causal loop diagram in this study.

As the objective of this study is to identify the interconnectivity and interrelationship between different knowledge areas in PMBOK. The activities in Figure 4.1 are further grouped into a different knowledge area that are related to the activities. As far as the knowledge areas of project management are concerned, there are five knowledge areas identified as dynamic factor that are possible to influence the performance of activities during the pre construction project stage. Procurement management, scope management, stakeholder management, integration management, and human resource management are the knowledge areas that are identified.

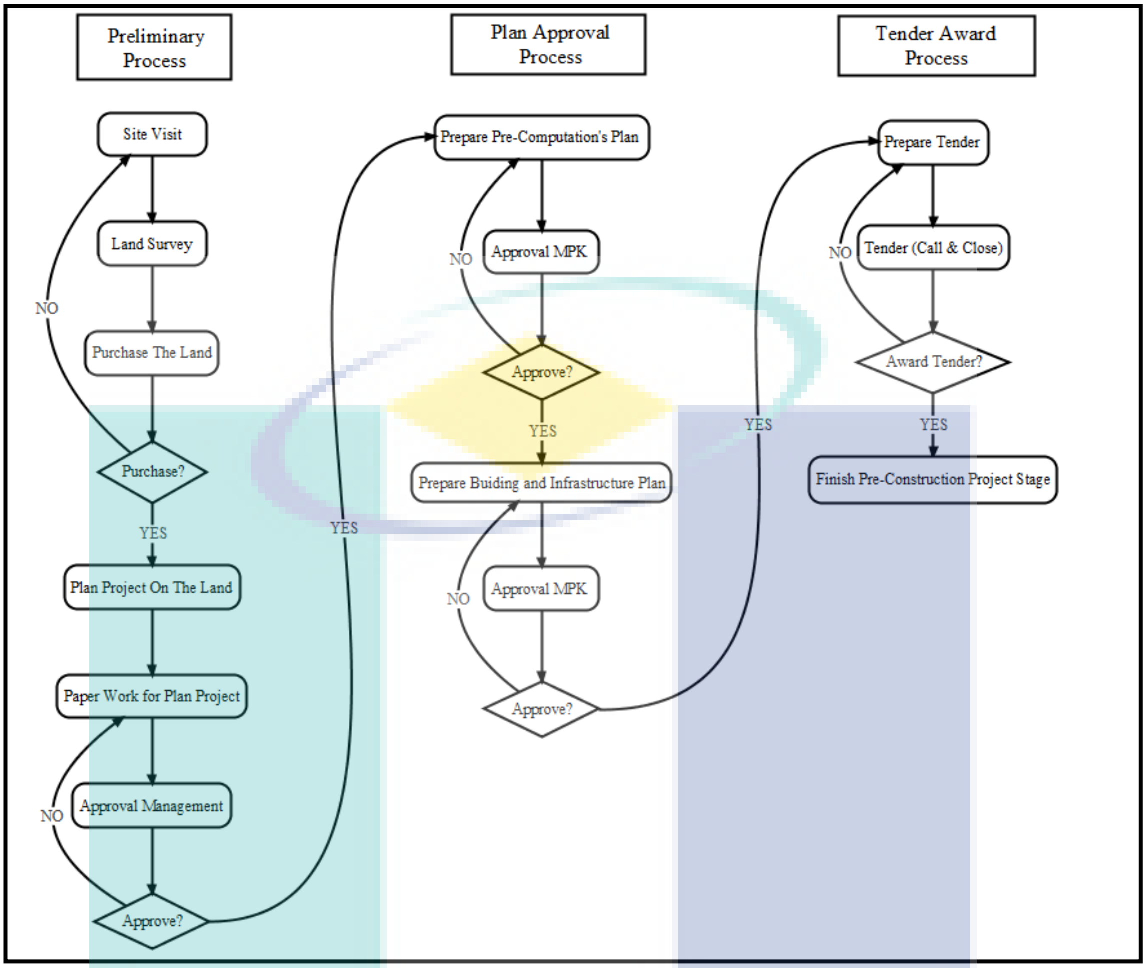

Figure 4.1 Mental model for pre construction project stage

4.3 Developing a Causal Loop Diagram

This section had explained how the activities are grouped based on different knowledge areas in PMBOK. Besides that, it also discussed and illustrated the interrelated activities that were grouped into different knowledge areas and how different knowledge areas are interrelated and interconnected in this study by a causal loop diagram. A causal loop model will be constructed to address the purposes of this section. The causal loop that is constructed will be more detailed compared to the mental model. It is because, to construct the causal loop model of diagram there is a need for identifying additional related variables that can influence or influence the change in each group of knowledge area. All this information is gathered during several interview sessions with the project manager.

4.3.1 The Procurement Management Causal Loops

Procurement management is the knowledge area that is important for the project managers to manage the project process, to purchase required products or services outside of the project team. The organization needs to deal with the outsider, which the organization could be either a buyer or seller of the product. Based on the sub mental models in the Figure 4.2, it has shown some activities that are grouped under the procurement management area. It is because the purpose of those activities is to purchase the land and those activities which are related to the procurement management knowledge area.

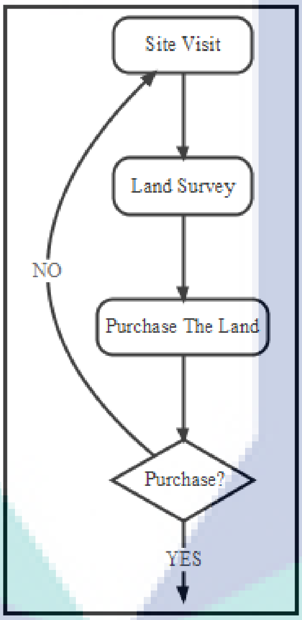

Figure 4.2 Sub mental model for procurement management

During this stage, the project manager needs to manage the process to purchase the land. Besides that, the project manager also needs to manage the process of conversion of land status to the land suitable for construction project. In the process to buy the land, it involves a lot of activities such as searching for the land, studying the land to define the land suitability, solving the existing problems, and then preparing a contract as an attempt to purchase the land. However, if these activities are not managed, understood and controlled properly, it will lead the project to be over scheduled. There is a need to understand the feedback causes between these activities to simplify the project manager's task. The inability of mental model to capture the feedback causal, causal loop diagram is illustrated.

Figure 4.3 shows the causal loop diagram for activities that are categorized in procurement management and in preliminary process. This figure illustrates the feedback process to purchase the land. Loop 1 explains that an increase in studying the land, increase in the expert person involved, increase in managing procurement and therefore increases the purchase the land. After that, there is an increase in suitable land and then a reduction in studying the land. However, Loop 2 describes that an increase in studying the land, increases and defines the land problem, increases hold purchase of the land, increases the cost and then reduces the procurement management. In order to solve the problem by making a reduction in land purchase in Loop 2, as the problem solving increase so does the cost increase. Then the procurement management also increases, resulting in the increase in the purchase of the land and increase in the suitability of the land, but reduces in study of the land.

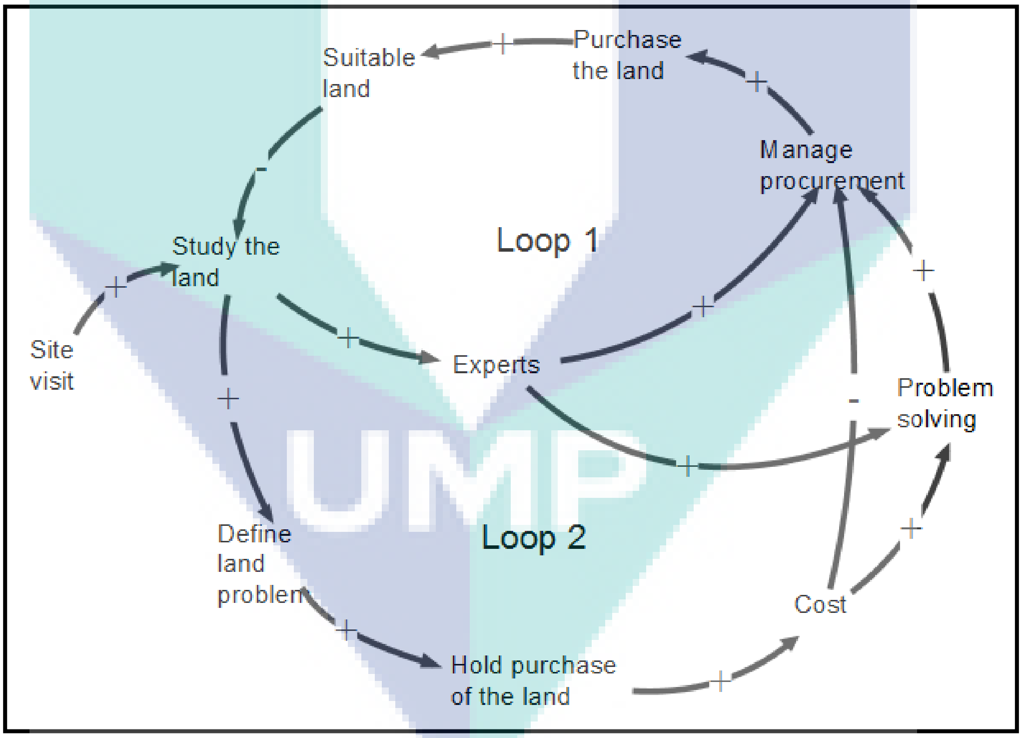

Figure 4.3 Causal loop diagram for procurement management

4.3.2 The Scope Management Causal Loops

Scope management is the process to include the activities that are required for the project, and to ensure only the activities are required to complete the project successfully are included in the project. As shown in Figure 4.4, those activities are grouped under scope management because the aim for those activities is to control the scope change in order to accelerate the construction of the paperwork for the project plan. It is applicable to the scope management knowledge area.

In the planning stage, there is very high possibility for the scope project to change. It is because during this process, the proposal of the project within the construction conditions receives a lot of addition and reduction of the information. During this stage the implementation of the scope management knowledge area is very necessary, in order to manage and control the scope change from affecting this process from becoming longer. The clear feedback about the activities are explained in the causal loop diagram

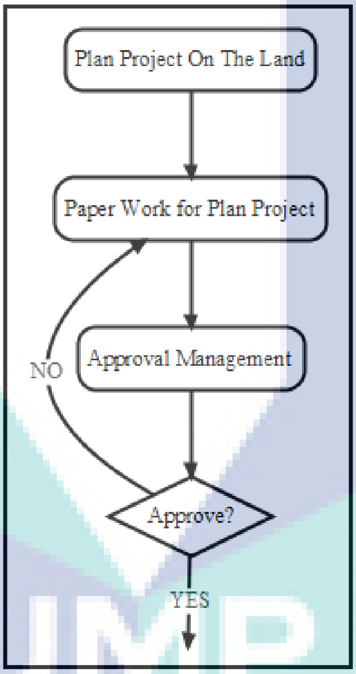

Figure 4.4 Sub mental model for scope management

Next, Figure 4.5 shows the causal loop diagram for activities that are categorized under scope management during preliminary process. The aim of these loops is to manage the scope change. This figure describes how changes in the project scope will have an impact on the process to finish the paper work of the project. Loop 3 has explained an increase in planning project on the land, increases the involvement of consultants. This will further increase in managing the scope and increasing the possibility of the paperwork being finished. Furthermore, in Loop 4 starts by an increase in planning project on the land, increases the market demand survey, increases the additional activities, increases project scope change, which will cause a decrease in managing the scope and then causing the process of paperwork to finish become less. A suggestion to improve the result in Loop 4, after the project scope change increases, the project review increases, and then managing the scope increases and result in an increase in the paperwork of the project to be completed.

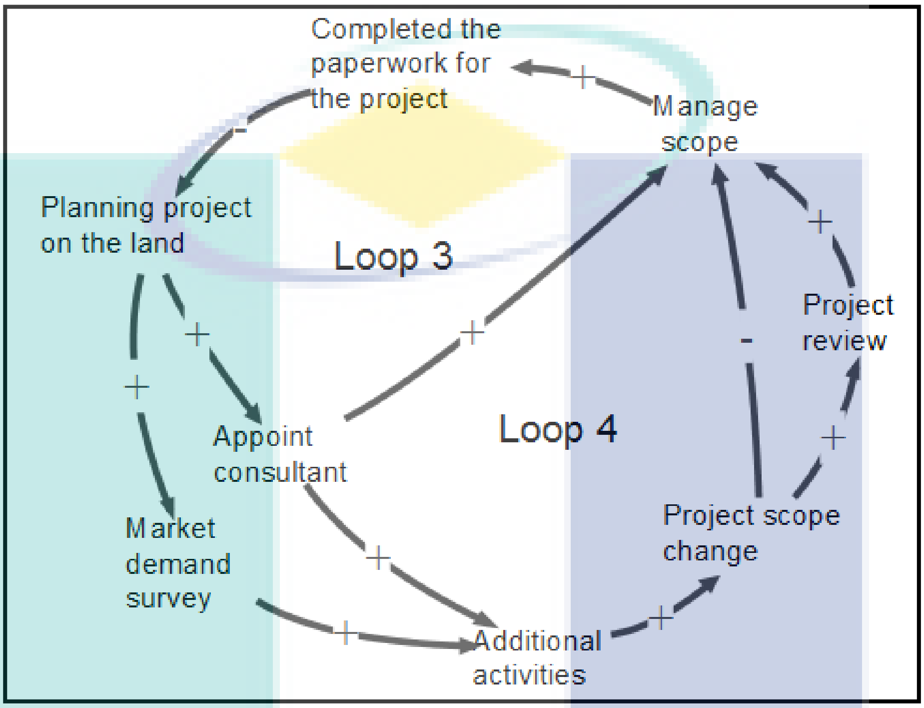

Figure 4.5 Causal loop diagram for scope management

4.3.3 The Stakeholder Management Causal Loops

Stakeholders are the individuals or groups that could have an impact or be impacted by the project. Besides, stakeholder management is the processes to identify, analyse, and plan to engage with the stakeholders. Figure 4.6 shows the activities that are categorized under stakeholder management. Getting approval MPK for the pre computation plan is a very important part in this stage. By getting the approval from MPK, the organization will be given permission from MPK to carry out the project. If the approval from MPK takes a long time, the project also will have to be delayed. If MPK has not given the permission, the project cannot be carried out. Hence, these activities are grouped under stakeholder management

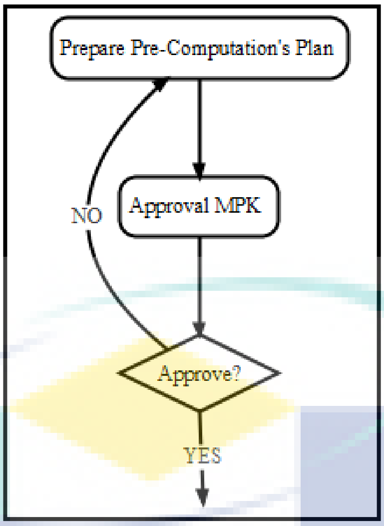

Figure 4.6 Sub mental model for stakeholder management

Figure 4.7 shows the explanation in detail for the casual feedback in stakeholder management. This is the loop for stakeholder management activities that are involved during the plan approval process. The main purpose of these loops is to achieve the plan approval from MPK. The plans that should be built for this project are three plans, which are pre computation plan, building plan, and infrastructure plan. Pre computation plan is the first plan that needs to be built and to get the MPK approval, only then other plans can be built. Loop 5 illustrates the feedback process to achieve MPK approval for the pre computation plan. Loop 5 starts with an increase in preparing project plans, increases the completion of the pre computation plan, and then increases the approval MPK.

However, when the approval of MPK increases, the screening by MPK also increases, followed by increase in the work errors and increase in preparing project plans. The increasing work error causes the probability of the loop to begin again is possible. Therefore, Loop 6 is needed to control the increasing work error. Loop 6 starts with an increase in MPK approval, increase screening by MPK, increases rework and then work error can be reduced that results in increase in MPK approval

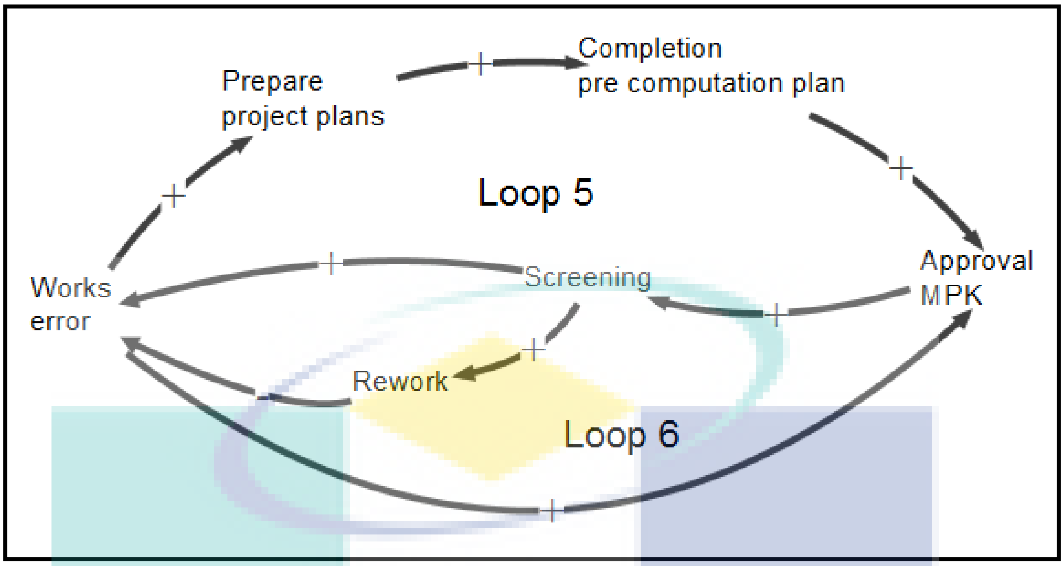

Figure 4.7 Causal loop diagram for stakeholder management

4.3.4 The Integrated Management Causal Loops

The integration management is the process to combine the various processes and coordinates of all aspects of the processes while completing the project. This is the situation where the individual activities interact together with other activities. As shown in Figure 4.8, the process is to prepare the building plan and the process is to prepare an infrastructure plan by combining to complete the activities. In order to manage these activities, the implementation of the integration management in PMBOK is required. The detail feedback causal for this knowledge area is explained clearly in the causal loop diagram.

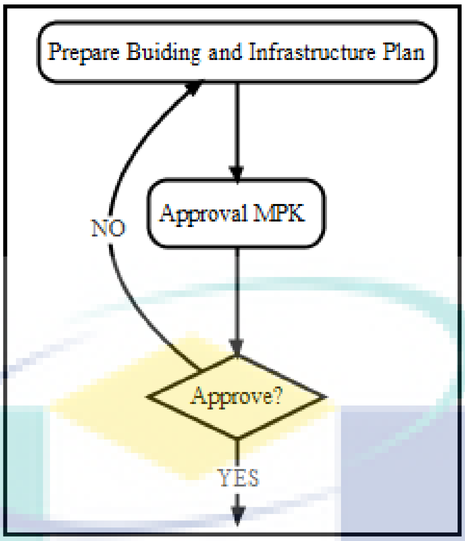

Figure 4.8 Sub mental model for integrated management

Figure 4.9 illustrates the causal loops for activities that are involved in the integration of management activities during plan approval process. The objective of these loops is to integrate the activities in order to complete the building plan and the infrastructure plan for achieving the approval MPK faster. The Loop 7 begins with an increase in preparing project plans, increases integrating activities, increases completion building plan and infrastructure plan, therefore the approval MPK increases. Besides that, increase in approval MPK, increases screening by MPK and then increases work error. The enhancement in work error will lead the feedback process of the project starting from the begining again. So the alternative is to solve the enhancement work error by implementing Loop 6 same as in Figure 4.7. Loop 6 explains an increase in approval of MPK, increases screening by MPK, then increases rework. Therefore, the work error reduces and increases the approval from MPK.

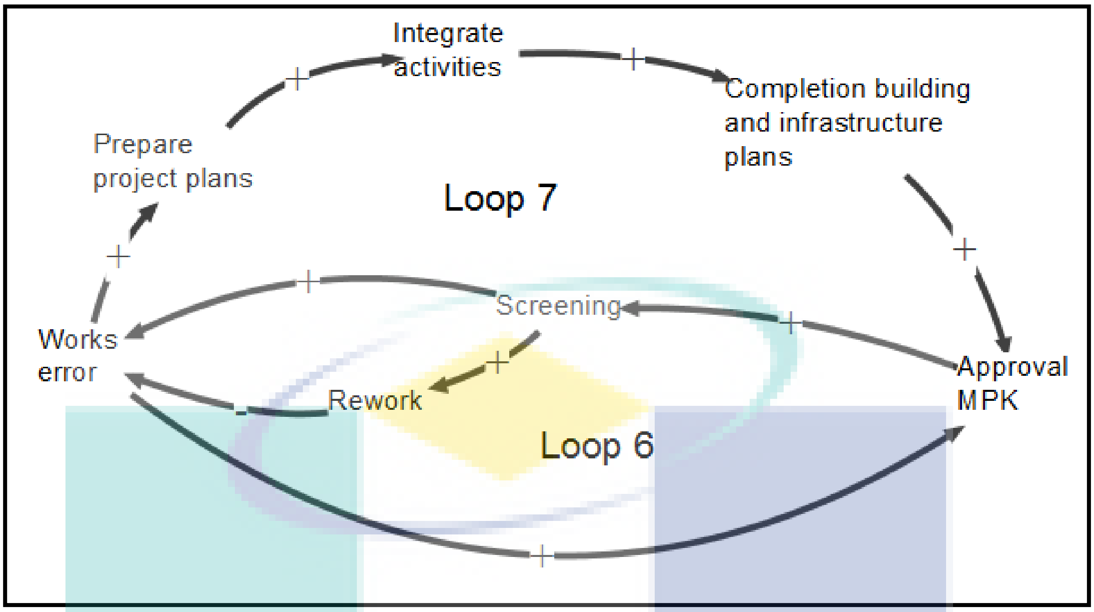

Figure 4.9 Causal loop diagram for integrated management

4.3.5 The Human Resource Management Causal Loops

Human resource management is the knowledge areas that discusses about the process to manage the project team starting from hiring, training, and until managing the human resource. Figure 4.10 shows the main activities that are needed for recruitment of human resources. This stage is the process to open the tenders to call contractors for conducting recruitment of workmen force. This process is required for human resource management, therefore these activities are grouped under human resource management knowledge areas.

During hiring the human resource for the project construction, the detailed scope of tender requirement is constructed. It is to ensure the contractors that accept the tender are from productive and experience contractors with the tender that is available. However, there is a negative effect if the requirement of tender is too high, which then the tender acceptance will be decreased. In order to solve the problem, the advertisement of the tender must be publicized widely. The feedback causal is shown in detail in the causal loop diagram.

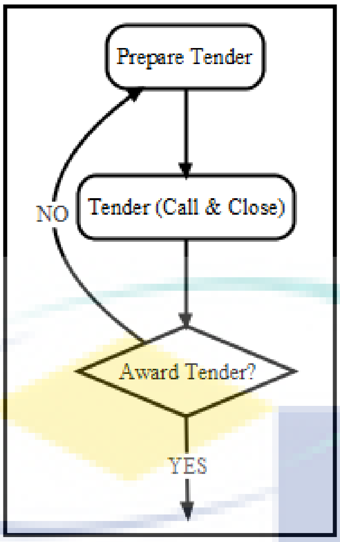

Figure 4.10 Sub mental model for human resource management

Figure 4.11 shows the causal loops for the activities that are grouped under human resource management in the tender process. The purpose of this causal loop diagram is to understand the process to achieve the tender award. Loop 8 describes an increase in preparing tender, increases detail tender's scope, and increases the tender requirement. However, tender reduces, then it reduces analyzing the acceptance and also reduces the award tender. If the award of tender reduces, it will affect the possibility of feedback loop process to restart again. Then, Loop 9 suggests with an increase in the advertisement will increase the accepted tender. When accepted tender increases, it increases the analyzing of the acceptance, and the final result will increase the award tender.

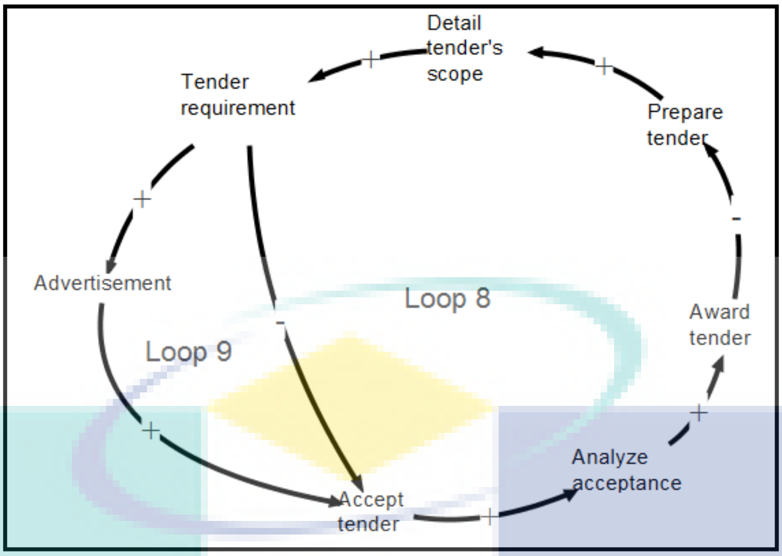

Figure 4.12 Causal loop diagram for human resource management

4.3.6 The Complete Causal Loop Diagram for Different Knowledge Areas

After explaining each knowledge area group and its causal loop diagram, Figure 4.12 captures the combination and interrelation between all the knowledge areas' groups in a complete causal loop diagram for different knowledge areas in pre construction project stage. Those knowledge areas' groups are procurement management causal loops, scope management causal loops, stakeholder management causal loops, integration management causal loops, and human resource management causal loops that have been already explained before this. The main function of this large causal loop diagram is to see and understand the interconnectivity and interrelationship between different knowledge areas in PMBOK for this study. The change that happens in procurement management variables may effect the change in scope management variables.

Furthermore, this diagram also maps out the dynamics hypothesis that appear in the project in a broad view. Project managers can see the difference between the mental model and the causal loop model that shows the various nonlinear relationships that is inherent in the activities of the pre construction project stage. All those nonlinear relationship is needed to be understood and managed by project manager in order to improve the performance on pre construction project stage.

Nevertheless, after the construction model of the causal loop diagram is completed. The next step in the system dynamics process is to create stock and flow diagram that can simulate the data by computer software. The creation of stock and flow diagram is translated from causal loop diagram information. This stock and flow process will be explained in the next discussion.

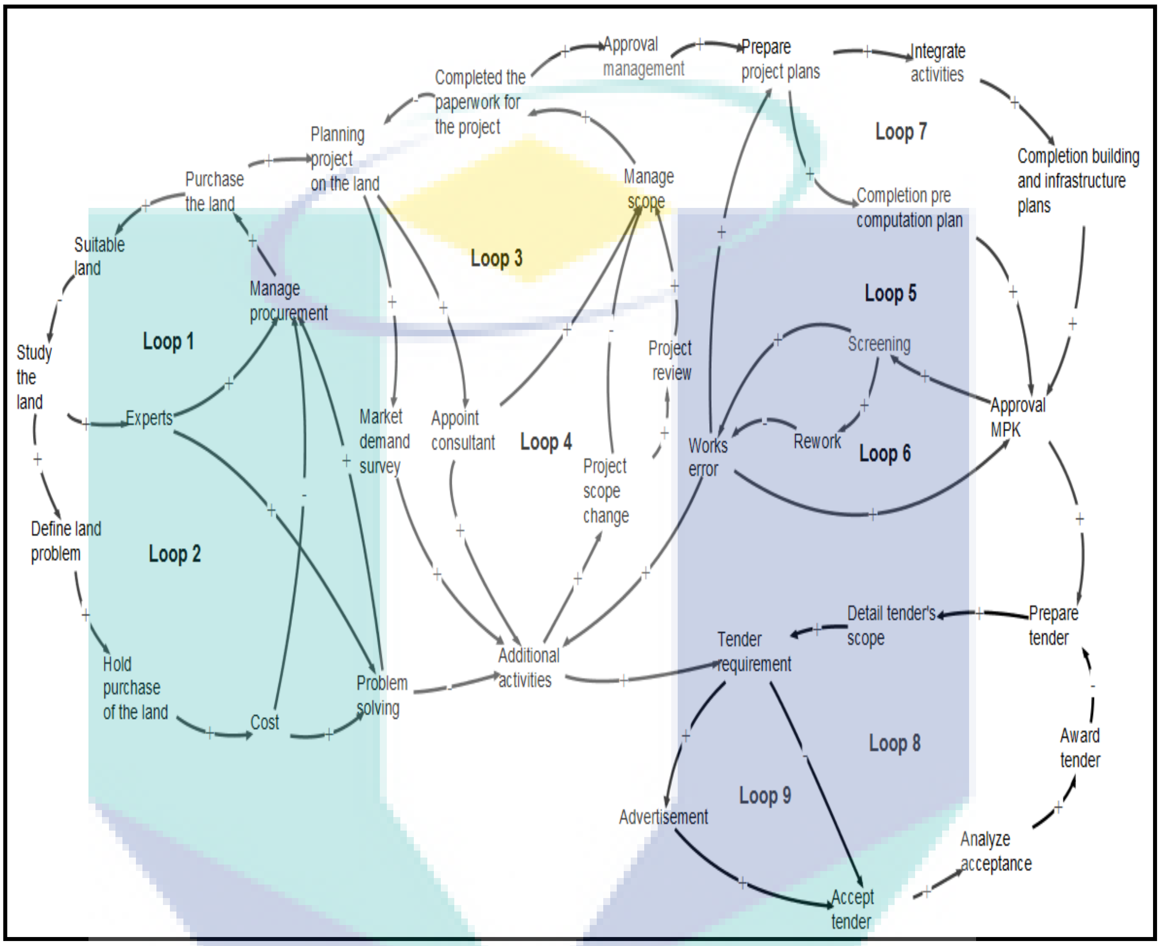

Figure 4.12 Overall causal loop diagram for the project

4.4 Summary

As a summary, knowledge areas in PMBOK are required to be implemented in the construction project as one of the best guidelines for project manager to manage the project effectively. However, in order to understand the problem that appear in the project, the project manager needs to understand the casual feedback in the project within a larger scope. It is to see what are the variables that are interrelated that causes the problem. Because of that, the development of causal loop diagram is necessary as to capture the dynamics hypothesis that occur during the project. Through the construction of the completed causal loop diagram, the first objective of this study, to understand the interconnectivity and interrelationship between different knowledge areas in PMBOK is answered.

CHAPTER 5

SYSTEM DYNAMICS SIMULATION MODEL

5.1 Introduction

In the process of constructing the system dynamics model, the causal loop diagram has to be developed first. After the causal loop diagram has been developed and discussed in the Chapter 4, the process to construct the system dynamics model continues by developing a stock and flow diagram using iThink computer software. This chapter will discuss in detail about the system dynamics simulation model and its implication.

This chapter begins with the discussion on the stock and flow diagram construction, followed by explanation of the stock and flow diagram for each knowledge area that is related, which are procurement management, scope management, stakeholder management, integrated management, human resource management, and finally the complete stock and flow diagram for pre construction project stage is presented. Then, the simulation result for each knowledge area are discussed and the project performance is defined. Next, the validation and verification of the model is presented, followed by policy suggestion. Before ending this chapter, the conclusion of this chapter is discussed.

5.2 Stock and Flow Diagram Construction

Developing the stock and flow diagram is an important part in the proses to develop a system dynamic model. The stock and flow diagram was constructed by using iThink software that was simulated by computer. The information and the interrelation between the subsystem in the stock and flow diagram is based on the causal loop diagram that has already been constructed before in Chapter 4. Causal loop diagram can not simulate the data, therefore causal loop diagram information is translated into stock and flow diagram to undergo the simulation process

The purpose of constructing the stock and flow diagram is to test the dynamic relationship between variables and the model. It is also to address a specific question, which is to understand the interconnectivity and interrelationship between different knowledge areas in PMBOK. It models the problem but not the system.

This model will to show how the duration of the project in this study can be reduced by two suggested strategic for the project manager of the construction project. Firstly by integrating some of the activities that are conducted by different parties but operated one by one. Second by increasing some human resorces in certain processes in order to reduce the delay.

Therefore, the data that is included in the model is quantitative data from actual progress in pre construction stage of a construction project case study. A project is known as consistent when there is a series process of activities that is needed to be done over time. Therefore, the stock and flow diagram in this study is developed in sequence as shown in Figure 5.1.

Figure 5.1 shows the complete stock and flow diagram for processes that is required within the pre construction project stage. The processes start from a procurement management process, then followed by a scope management process, stakeholder management process, integrated management process, and human resource management process. The stock and flow diagram of the five knowledge areas processes are discussed in detail in the following section.

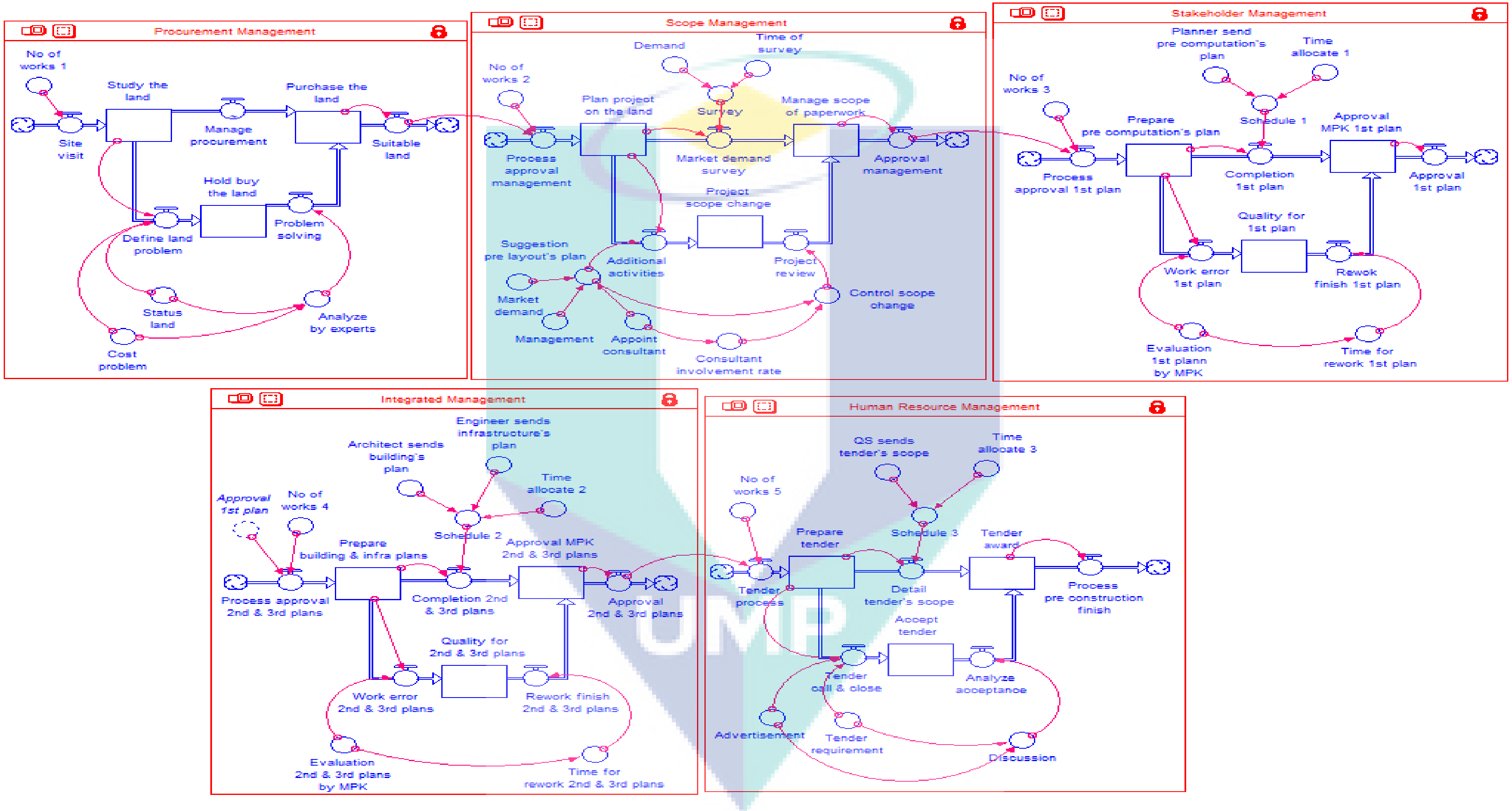

Figure 5.1 Complete stock and flow diagram for pre construction project stage processes

5.2.1 Stock and Flow Diagram for Procurement Management

Procurement management is the first process conducted in this pre construction project stage. Figure 5.2, shows the dynamics model of stock and flow diagram for procurement management process. This diagram tries to capture the major feedback causal that influences the procurement management process behavior. The interrelated variables in this stock and flow diagram of procurement management is translated from the causal loop diagram of procurement management in Figure 4.3.

The procurement management process starts with a site visit activity and study of the land. In order to purchase the land, the procurement management process is applied. The total number of works, that is the procurement management process that needs to complete this process is drained by *Site visit* flow that is generated by *No. of works 1* connector, which is the first sub model in the pre-construction project process. The amount of work that is needed is 4 works and then that amount of works enters into *Study the land* stock to accumulate the amount of work needed in procurement management before flowing out according to the amount of activities and the time required for the next activities. The *Manage procurement* flow start to flow out 2 works within 1 month from the stock to enter into the next stock, which is *Purchase the land* stock. The formulations of those elements are:

No. of works 1 convertor = 4 Works
Site visit flow = No_of_works_1
Manage procurement flow = 2 Works/ 1 Month

However, in conducting the procurement management process, the land problems are defined. Those problems are mainly related to land status and cost and then causes the process to purchase the land to become pending. The problem solving process is needed in the way to facilitate the process to purchase the land. In the Figure 5.2, *Define land problem* flow functions to flow out the other of 2 works for the problem that exist after studying the land and entering into *Hold purchase the land* stock. The *Cost problem* convertor and the *Land status* convertor affects this flow. In the *Hold the land stock*, the number of works that cause the process of purchasing the land pending is accumulating**.** Then *Problem solving* flow is used to flow out the works into the *Purchase the land* stock in an effort to solve those problems within 10 months. The *Problem solving* flow is influenced by *Analyze by experts'* convertor.

At the end of this process, all the amount of works accumulates inside the *Purchase the land* stock and then those works will drain out after the procurement management process completes through *Suitable land* flow to allow the next sub model for functioning. It consists of the following interrelated subsystems that cause this stock and flow diagram function:

Define land problem flow = IF (Study_the_land=2) THEN (Cost__problem+Status_land)ELSE 0

Land status convertor = 1

Cost problem convertor = 1

Problem solving flow = Analyze__by_experts

Analyze by experts convertor = (Status_land+Cost__problem)/10 months

Suitable land flow = IF (Purchase_the_land=4) THEN 4 ELSE 0

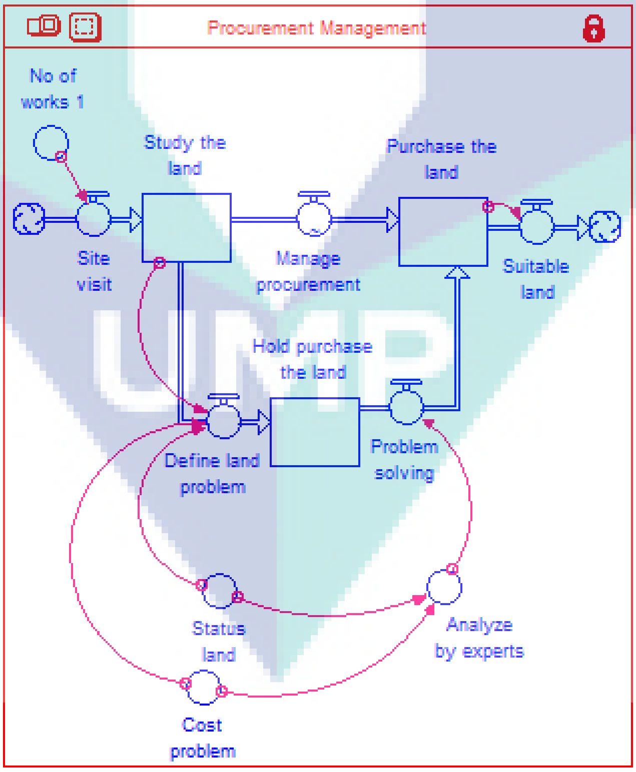

Figure 5.2 Stock and flow diagram of procurement management process

5.2.2 Stock and Flow Diagram for Scope Management

After the procurement management process is completed, only then the second process can begin to be conducted, which is the scope management process. Figure 5.3 illustrates the stock and flow diagram for the scope management process. The purpose of this model is to capture the variables that affect the scope change in order to complete the paperwork of the project for achieving the plan approval from management. The development of this figure is acquired from the information in causal loop diagram of scope management in Figure 4.5.

The concept of the scope management process can be identified from this diagram in order to achieve the objective of the scope management process. The objective is to control the project scope change in an effort to achieve the paperwork approval from management. The process begins with the activity to plan the project on the land and then survey the market demand for the project. After the market demand survey is completed, the suggested pre layout plan will be constructed.

From the Figure 5.3, *Process approval management* flow is to drain the amount of work that is needed for the overall activities during the scope management process, that is influenced by *No. of works 2* convertor after the previous process is completed. The number in the name of this convertor has represented the number of this process. From the flow, 8 works of data is entered into the *Plan project on the land* stock. This amount of work is the total number of works that scope management process needs to complete the process. After the amount of works is accumulated in the stock, *Market demand survey* flow starts operating to flow out 2 works within 3 months from previous stock into other stock which is *Manage scope of paperwork* stock. This flow is controlled by *Demand* convertor, *Time of survey* convertor, and *Survey* convertor through such equations below:

No. of works 2 convertor = 8 (works)

Process approval management flow = IF (Suitable__land=4) THEN No_of__Works_2 ELSE 0 *Market demand survey* flow = IF (Plan_project__on_the_land=8) THEN Survey ELSE 0 + (IF (Plan_project__on_the_land=(8-Survey)) THEN Survey ELSE 0) + (IF (Plan_project__on_the_land=(8-2*Survey)) THEN Survey ELSE 0)

Survey convertor = Demand/Time_of_survey

Demand convertor = 2 works

Time of survey convertor = 3 months

However, the suggested pre layout plan for the project is influenced by many causes, which are based on market demand, management, and consultant involvement. Because of that, the additional activities for the project scope increases and causes the project scope to change frequently. Therefore, the consultant that is appointed needs to review the project scope in order to control the scope change. From that, the paperwork of the project can be completed within schedule and obtain the necessery approval from management.

Based on Figure 5.3, after the *Market demand survey* flow has done the work, the next *Additional activities* flow is functioning. It is to drain the work that is influenced by the *Suggestion pre layout's plan* convertor into *Project scope change stock*. Besides, the *Suggestion pre layout's plan* convertor also is influenced by other elements, which are *Market demand* convertor, *Management* convertor, and *appoint consultant* convertor. Each convertor includes within *Suggestion pre layout's plan* convertor consist with 2 works for each. During the accumulation of works in *Project scope change* stock, the *Project review* flow start to flow out the accumulation into *Manage scope of paperwork* stock that is controlled by the *Control scope change convertor* and the *Consultant involvement rate* convertor. After all the works have already been accumulated inside *Manage scope of paperwork* stock, then the amount of works drain out through the *Approval management* flow to allow the next process to function. The equation of the elements are:

Additional activities flow = IF (Plan_project__on_the_land=6) THEN Suggestion__pre_layout's_plan ELSE 0

Suggestion pre layout's plan convertor = (Appoint_consultant+Market__demand+Management)

Appoint consultant convertor = 2 works

Market demand convertor = 2 works

Management convertor = 2 works

Project review flows = Control_scope__change

Consultant involvement rate convertor = Appoint_consultant*4.5 months

Control scope change convertor = Suggestion__pre_layout's_plan/Consultant_involvement_rate

Approval management flow = IF (Manage_scope_of_paperwork>7) THEN 8 ELSE 0

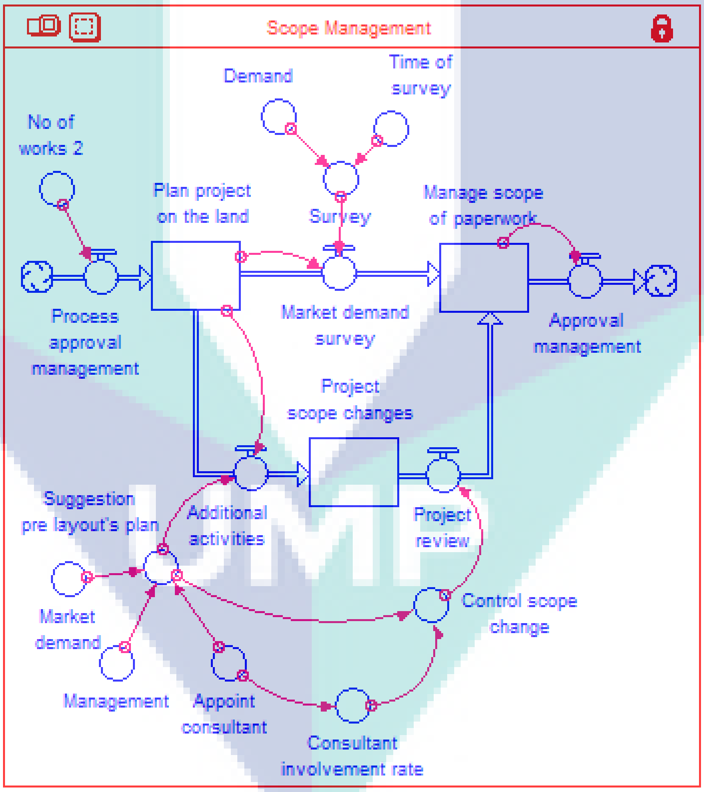

Figure 5.3 Stock and flow diagram for scope management process

5.2.3 Stock and Flow Diagram for Stakeholder Management

The process of stakeholder management is conducted after the scope management process is completed. Figure 5.4 shows the stock and flow diagram for stakeholder management process. This diagram is developed based on the causal loop diagram for stakeholder management in Figure 4.7. The stakeholder management process involves two sections. The first is the section to complete the pre computation plan by the planner and sent to the MPK for getting plan approval and the second section is the process to make corrections and amending the plan after having been reviewed by MPK. The number of plans that are needed to get MPK approval is three plans and the pre computation plan is the first plan.

The main purpose of this process is to achieve the MPK approval for this first plan in order to get permission to run the project. This process begins with preparing the pre-computation plan by the planner and sent to MPK. The *Process approval 1st* plan flow is drained 5 works that is needed during conducting the stakeholder management process into the *Prepare pre computation plan* stock after previous scope management process is complete. This flow is influenced by *No. of works 3* convertor. Then, the *Prepare pre computation plan stock* starts to flow out 3 works in 4 months through *Completion 1st plan* flow into *Approval MPK 1st plan* stock. This flow is influenced by *Planner send pre computation plan* convertor, *Time allocate 1, and Schedule 1.* The number in the name for both convertors is to differentiate between the convertors that is used in this process with the other convertor of the same name in the next sub model. The formulation for the related element is shown below:

No. of works 3 convertor = 5 works

Process approval 1st plan flow = IF (Approval_management=8) THEN No_of__works_3 ELSE 0

Completion of 1st plan flow = IF (Prepare__pre_computation's_plan=5) THEN Schedule_1 ELSE 0 + (IF (Prepare__pre_computation's_plan=(5-Schedule_1)) THEN Schedule_1 ELSE 0) + (IF (Prepare__pre_computation's_plan=(5-2*Schedule_1)) THEN Schedule_1 ELSE 0) + (IF (Prepare__pre_computation's_plan=(5-3*Schedule_1)) THEN Schedule_1 ELSE 0)

Planner sends pre computation plan convertor = 3 works

Time allocates 1 convertor = 4 months

Schedule 1 convertor = Planner_send_pre_computation's__plan/Time__allocate_1

However, some errors are identified after the pre computation plan is evaluated by MPK. In order to fulfill the quality and the requirement from MPK, rework is conducted and then correction plan is sent back to MPK for obtaining approval. As in Figure 5.4, the *Prepare pre computation plan stock* drain out another 2 works through the *Work error 1st plan* flow to enter inside the *Quality for 1st plan* stock. The *Work error 1st plan* flow is influenced by the *Evaluation 1st plan by MPK* convertor.

The work that is accumulated inside the *Quality for 1st plan* stock are drained out within 3 months through the *Rework finish 1st plan* flow and then enters into the *Approval MPK 1st plan* stock until completed. That flow is influenced by the *Time for rework 1st plan* convertor. When all the works in this process is completed and accumulated inside the *Approval MPK 1st plan* stock, then all the works are drained out from the stock through the *Approval 1st plan* flow to permit the next process to begin. The following equations describe how those elements function:

Work error 1st plan flow = IF (Prepare__pre_computation's_plan=2) THEN 1st_plan_screening_by_MPK ELSE 0

Evaluation 1st plan by MPK convertor = 2 works

Time for rework 1st plan convertor = Evaluation_1st_plan_by_MPK/3 months

Reworks finish 1st plan flow = Time_for__rework_1st_plan

Approval 1st plan flow = IF (Approval_MPK_1st_plan>4.2) THEN 5 ELSE 0

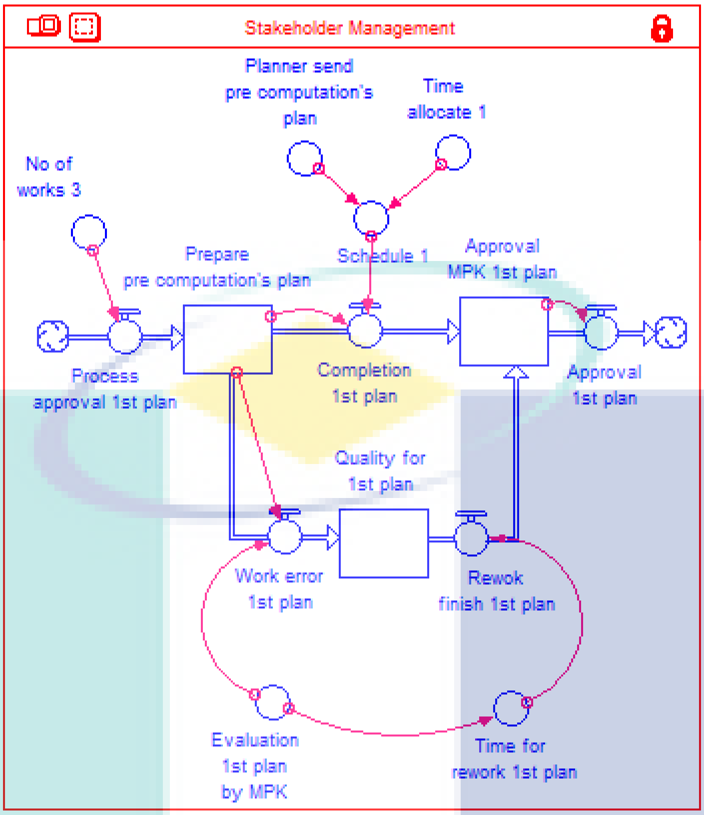

Figure 5.4 Stock and flow diagram for stakehoder management process

5.2.4 Stock and Flow Diagram for Integrated Management

Figure 5.5 illustrates the stock and flow diagram of the integrated management process. This integrated management process functions, after the stakeholder management process is completed. The construction of this diagram is as a result from the causal relationship within the causal loop diagram for integrated management is shown in Figure 4.9. The main purpose for this stock and flow diagram is to integrate the process of competing two plans at the same time in order to obtain the plan approved by MPK.

This integrated management process begins with the preparation of the plans for building plans and infrastructure plan simultaneously. Both plans are integrated together at the same time because both plans are prepared by different people. Preparing the building plan is done by architects and preparing the infrastructure plan is done by engineers. These two plans are needed to be completed by the time allocated in an effort to submit for getting approval from MPK.

In the Figure 5.5, the model starts from the *Process approval* 2^{nd} *&* 3^{rd} *plans* flow that drain the total number of works required to complete this integrated management process into the *Prepare building & infra plans* stock, which is influenced by the *No. of works 4* convertor. The total number of works that is accumulated in the *Prepare building & infra plans* stock is 10 works. Then, 5 works are drained out within 4 months from that *Prepare building & infra plans* stock to enter for the next *Approval MPK* 2^{nd} *&* 3^{rd} *plans* stock through the *Completion* 2^{nd} *&* 3^{rd} *plans* flow. This flow is controlled by four convertors which are *Architect sends building plan convertor, Engineer seeds infrastructure plan* convertor, *Time allocates 2* convertor, and *Schedule 2* convertor. The equations for related elements are mentioned below:

No. of works 4 convertor = 10
Process approval 2^{nd} *&* 3^{rd} *plans* = IF (Approval__1st_plan=5) THEN No_of_works_4 ELSE 0
Completion of 2^{nd} *&* 3^{rd} *plans* = IF (Prepare_building_&_infra_plans=10) THEN Schedule_2 ELSE 0 + (IF (Prepare_building_&_infra_plans=(10-Schedule_2)) THEN Schedule_2 ELSE 0) + (IF (Prepare_building_&_infra_plans=(10-Schedule_2-Schedule_2)) THEN Schedule_2 ELSE 0) + (IF (Prepare_building_&_infra_plans=(10-Schedule_2-Schedule_2-Schedule_2)) THEN Schedule_2 ELSE 0)
Architect sends building plan convertor = 3
Engineer sends infrastructure plan convertor = 2
Time allocate 2 convertor = 4 months
Schedule 2 convertor = (Architect_sends__building's__plan + Engineer_sends__infrastructure's__plan) /Time__allocate_2

After the plan has already be sent and screened by MPK, some errors are identified in order to improve the plans for quality specification and then rework is required. After the rework is finished, the second submission is made until MPK approves both plans. The model continues with the *Work error* 2^{nd} *&* 3^{rd} *plans* flow drained out 5 work remaining from the *Prepare building & infra plans stock* into the *Quality for* 2^{nd} *&* 3^{rd} *plans* stock. This flow is controlled by the *Evaluation* 2^{nd} *&* 3^{rd} *plans by MPK* convertor. Then, the *Rework finish* 2^{nd} *&* 3^{rd} *plans* flow drain out 5 works within 7 months into the *Approval MPK* 2^{nd} *&* 3^{rd} *plans* stock until rework is completed. After all the works has already been accumulated into the *Approval MPK* 2^{nd} *&* 3^{rd}

plans stock, the *Approval 2nd & 3rd plans* flow functions to drain out all the works from the stock in order to allow the next process to begin. The related equations are presented as below:

Work error 2nd & 3rd plans flow = IF (Prepare_building_&_infra_plans=5) THEN 2nd_&_3rd_plans, _screening_by_MPK ELSE 0

Evaluation 2nd & 3rd plans by MPK = 5

Reworks finish 2nd & 3rd plans flow = Time_for__rework_2nd_&_3rd_plans

Time for rework 2nd & 3rd plans convertor = Screening_2nd_&_3rd_plans_by_MPK/ 7 months

Approval 2nd & 3rd plans flow = IF (Approval_MPK__2nd_&_3rd_plans>9.0) THEN 10 ELSE 0

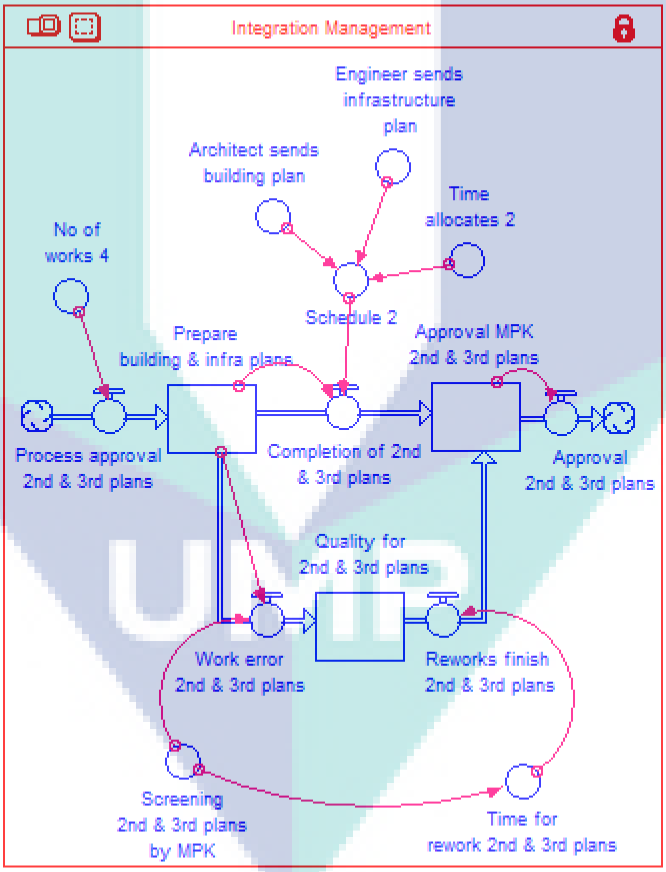

Figure 5.5 Stock and flow diagram for integrated management process

5.2.5 Stock and Flow Diagram for Human Resource Management

Figure 5.6 shows the stock and flow diagram for human resource management. This is the last process that involves in pre construction project stage. The relationship that is developed in the system is interpreted from the causal relationship in the causal loop diagram for human resource management in Figure 4.11. The aim of this process is to select the suitable recipients for awarding tenders for the project.

The first process starts with the activity to prepare the tender. The Quantity Surveyor (QS) is the person who is appointed to prepare the details of the tender's scope in the way to get the suitable recipients for tender award. The model in Figure 5.6 begins with the *Tender process* flow drains the amount of work that is required in the human resource management process to enter the *Prepare tender* stock after the integrated management process is completed. This flow is influenced by the *No. of works 5 convertor*. The amount of work that is accumulated within the *Prepare tender* stock is 7 works. Through the *Detail tender's scope flow,* 2 works are drained out within 2 months from the previous stock to enter into the next *Tender award* stock. The elements that influence this flow are *QS sends tender scope* convertor, *Time allocate 3 convertor,* and *schedule 3 convertor.* The equation related is as shown below:

No. of works 5 convertor = 7
Tender process flow = IF (Approval__2^{nd}_&_3^{rd}_plans = 10) THEN No_of_works_5 ELSE 0
Detail tender scope flow = IF (Prepare__tender=7) THEN Schedule_3 ELSE 0 + (IF (Prepare__tender=7-Schedule_3) THEN Schedule_3 ELSE 0)
QS sends tender's scope convertor = 2 works
Time allocates 3 convertor = 2 months
Schedule 3: QS_sends_tender_scope/Time__allocate_3

From the tender scope, tender requirement is generated and then an advertisement is conducted for tender calls and close. After the tender is closed, analyzing acceptance is carried out and suitable recipient is selected for tender award. The model is continued by the *Tender call & close* flow drains out 5 works from the *Prepare tender* stock to enter into the *Accept tender* stock. This flow is controlled by two convertors, which are *Advertisement* convertor and *Tender requirement* convertor. After the works have already been accumulated inside the *Accept tender* stock, the *Analyze acceptance* flow drains out all the works within 2 months, which is controlled by the *Discussion* convertor into the *Tender award* stock. *The Tender award* stock accumulates all the works until the human resource management process is complete. After that the *Process pre construction finish flow* functions to show that the processes in pre construction project stage is completed. The feedback structure equation is shown as below:

Tender calls & close flow = IF (Prepare__tender=5) THEN (Advertisement+Tender__requirement) ELSE 0

Advertisement convertor = 2 works

Tender requirement convertor = 3 works

Discussion convertor = (Tender__requirement+Advertisement)/ 2 months

Analyze acceptance flow = Discussion time

Process pre construction finish flow = IF (Tender_award=7) THEN Tender_award ELSE 0

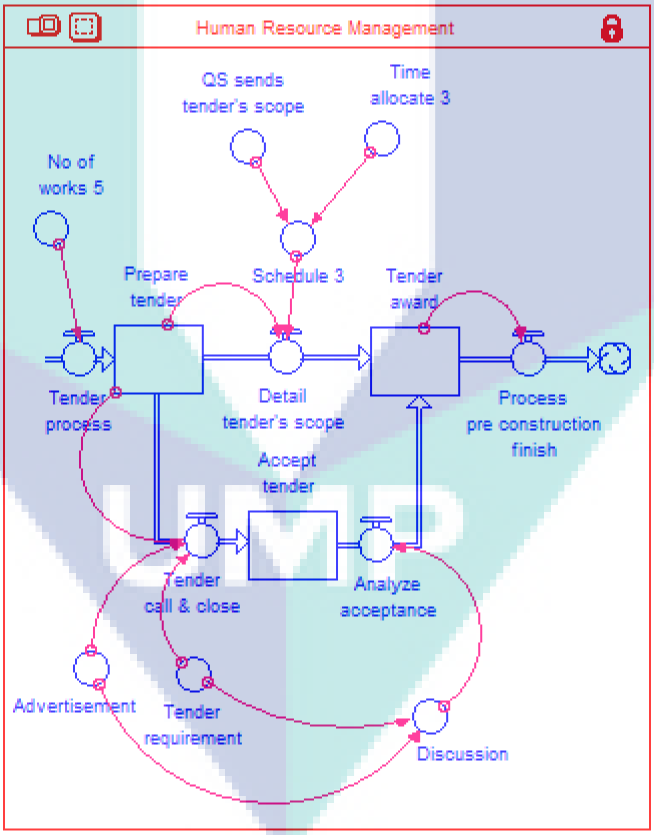

Figure 5.6 Stock and flow diagram for human resource management process

5.3 Model Validation and Verification

Before this model can be used to make recommendation for strategy implication, the process to test the model, whether the model structure responds logically or not is conducted. In order to test and build the confidence model, verification and validation on the model has to be implemented. Validation means to develop the right model, whereas verification means to develop the model right (Sterman, 2000). The process verification and validation are very important. The test that is conducted on the model as a part of the validation and verification process is explained below:

5.3.1 Face Validity

Face validity is a process to ensure that the model built is validated by the client (Damle, 2003). This study is conducted as a practical project in the real situation. During discussion and modeling session with the client, the causal relationship that is developed in the causal loop diagrams is validated by that client. Once the client has agreed with the model, the model is considered a valid model.

5.3.2 Extreme Condition Test

This test is used to validate the model structure in order to build confidence in the model structure (Wan et al., 2013). During conducting the test, the changing rate of flow parameters was conducted in order to assess whether the model is appropriate and function logically in a real system when subjected to changes in flow rate. Then the model is considered structurally valid. This test is conducted for each sub model as explained below:

1. Extreme condition test for procurement management sub model

Based on Table 5.1 the results shows the extreme condition on stock and flow diagram of procurement management (Figure 5.2). When the work available is changed to zero, there is no work that is accumulated inside the *Study the land stock.* It means no work that can generate the whole process. Meanwhile, if the *manage procurement flow* is zero, the work that is accumulated inside the *Hold purchase the land stock* is also zero. It is because when the intention and the process to purchase the land does not start (*Manage procurement flow*), there is no work to define the land problem and no work is required to hold the process of purchasing the land.

Table 5.1 Result for extreme condition on stock and flow diagram of procurement management

Extreme condition in procurement management process	Value	Test Result
Zero number of the *Site visit flow*	0	No work that accumulates in the *Study the land stock* and no work done for the whole process
Zero work for the *manage procurement flow*	0	No work that accumulate in the *Hold purchase the land stock* because do not define the problem of land

2. Extreme condition test for scope management sub model

Table 5.2 shows the result for extreme condition on stock and flow diagram of scope management (Figure 5.3). If the *Process approval management flow* is zero, then no work will be conducted in this process and cause the stock of *Plan project on the land* does not accumulate any works. Besides that, if the *Market demand survey flow* is zero, no additional activities is commenced that causes the project scope to change. It is because in this study, the main factor that causes the initial scope change change is based on market demand survey (design building and strategic location).

Table 5.2 Result for extreme condition on stock and flow diagram of scope management

Extreme condition in scope management process	Value	Test Result
Zero work for the *Process approval management*	0	No work that accumulates in the *Plan project on the land stock* and no work done for the whole process
Zero work for the *Market demand survey flow*	0	No work that accumulates in the *Project scope change stock* because the scope do not change

3. Extreme condition test for stakeholder management process

Next, Table 5.3 shows the extreme condition test of the result on the stock and flow diagram of stakeholder management (Figure 5.4). The same as the preceding discussion, If the *Process approval 1st plan flow* does not drain any work, there is no accumulation inside the *Prepare pre computation plan stock* will be produced. Therefore, no work is carried out in this stakeholder management process. Furthermore, if the *Completion 1st plan flow* is zero, this will cause the accumulation in the *Quality for 1st plan stock* empty because the plan is not completed yet and not reviewed yet by MPK.

Table 5.3 Result for extreme condition on stock and flow diagram of stakeholder management

Extreme condition in stakeholder management process	Value	Test Result
Zero work for the *Process approval 1st plan flow*	0	No work that accumulates in the *Prepare pre computation plan stock* and no work is done for the whole process
Zero work for the *Completion 1st plan flow*	0	No work that drains through the *Work error 1st plan flow* because no work error defined

4. Extreme condition test for integrated management process

As seen in Table 5.4, the results for extreme condition on the stock and flow diagram of integrated management (Figure 5.5) is presented. This result explains that if the *Process approval 2nd & 3rd plan flow* is set as blank, it means there is no flow that will enter into the *Prepare building & infra plans stock* and no flow will be drained out from the stock. All the process in this process becomes zero. In other condition, if the *Completion 2nd & 3rd plans flow* is zero, there is no work to complete the second and the third plans. Because of that, no work error is generated in the *Work error 2nd & 3rd plans flow*.

Table 5.4 Result for extreme condition on stock and flow diagram of integrated management

Extreme condition in integrated management process	Value	Test Result
Zero work for the *Process approval 2nd & 3rd plans flow*	0	No work that accumulates in the *Prepare building & infra stock* and no work is done for the entire process
Zero work for the *Completion 2nd & 3rd plans flow*	0	No work that drains through the *Work error 2nd & 3rd plan flow* because no work error defined

5. Extreme condition test for human resource management process

For the last, Table 5.5 explains about the extreme conditions that result on stock and flow diagram of human resource management as developed in Figure 5.6. When no work is drained through the *Tender process flow*, then it will cause the entire process in this human resource management not to function. Meanwhile, if the *Detail tender scope flow* is changed to become zero, the *Tender call & close flow* will not work. It is because only the tender scope is finished, the *Tender call & close flow* can work. Therefore, tender award will not happen.

Table 5.5 Result for extreme condition on stock and flow diagram of human resource management

Extreme condition in integrated management process	**Value**	**Test Result**
Zero work for the *Tender process flow*	0	No work that accumulates in the *Prepare tender stock* and no work is generated for the entire process
Zero work for the *Detail tender scope flow*	0	No work that drains through the *Tender call & close flow* because no work to develop the tender scope

5.3.3 Compare The Simulation Output With The Actual Project

The comparison between the simulation results of actual progress with the actual progress in the real situation, is the process to verify the model behavior (Lee, 2008). Based on Figure 5.7, the simulation results is developed approximately similar with the actual project. This comparison can verify the usability of system dynamics in developing a model in pre construction project stage as a project management method to plan and manage the complex project under dynamics situation. This model can show the interconnectivity and interrelationship between different knowledge areas in PMBOK during the pre construction project stage.

The actual progress of the pre construction project stage began on April 2010 and finished on September 2013, the actual duration that is used to finish the pre construction project is 42 months equivalent to 3 year 6 month. Besides, the simulated completion date of the project by system dynamics simulation was September 2013 that is same as well as actual progress. Besides, the total amount of work that was conducted in actual progress was 35 works whereas the simulation result approximately was similar with 35.04 works. It shows that the simulation results and the actual results was almost the same and verifies that the model behaviour is valid.

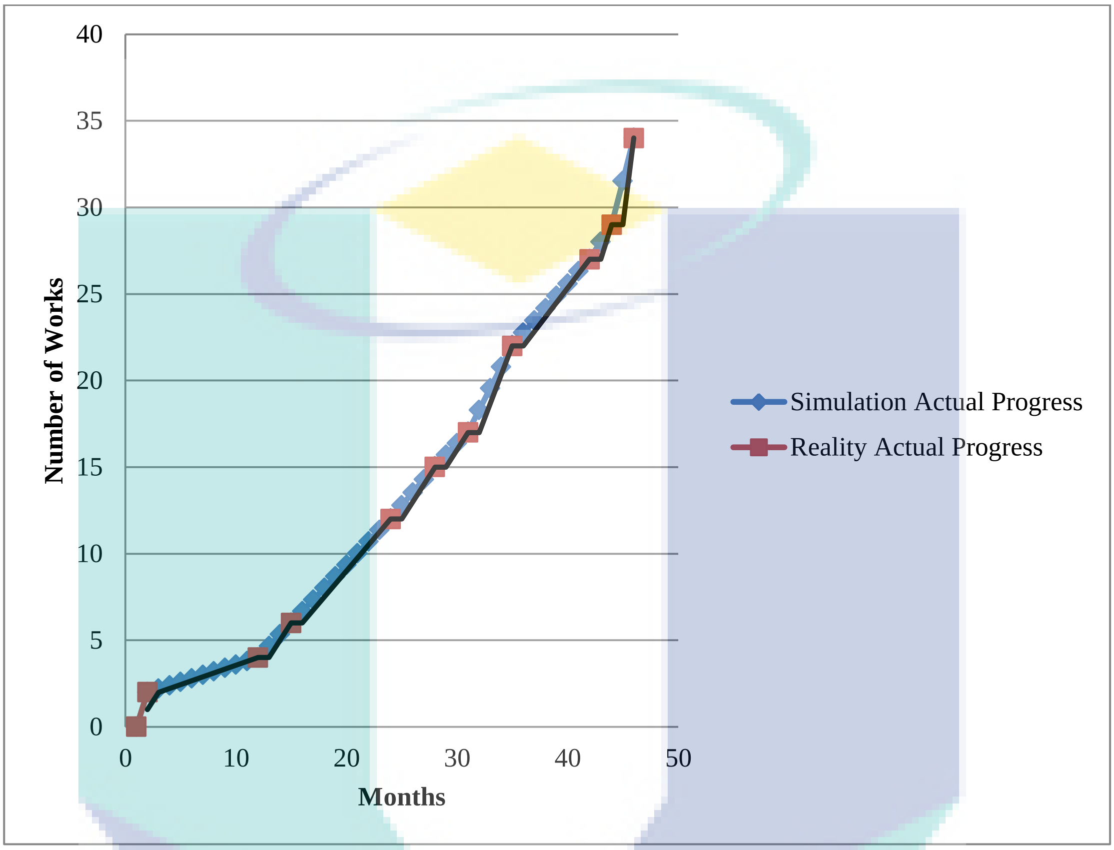

Figure 5.7 The comparison of the simulation output with the actual project

5.4 Simulation Results and Discussion

The results obtained from completed simulation will be discussed in this section. The process starts with the Procurement Management Process, followed by Scope Management Process, Stakeholder Management Process, Integrated Management Process, Human Resource Management Process and finally the combined results from the entire knowledge areas process. It is important to keep in mind that the system dynamics simulation is used to understand the problem, not the system. The simulation result describes the factors causing each knowledge areas process to be over scheduled. It also shows the performance for the actual process by comparing with process scheduled. A solution will be suggested later

5.4.1 Procurement Management Process

The simulation results of procurement management process was conducted to make a comparison between two different situations that were studied and tested in simulation model of Procurement Management Process. The result for both situations is presented in Table 5.6 and Figure 5.8. Situation Plan is the simulation result which is set as planned where the Situation Actual is the simulation result that is set as the actual situation.

Based on Table 5.6, Situation Plan represents an ideal case where the process of procurement management runs smoothly and goes as planned. The process is completed on schedule of 8 months. In Situation Actual however, the process took 3 months longer, where it completed in 11 months time, taking a 42.9% of schedule slippage for this procurement management process.

The gap which exists between Situation Plan and Situation Actual is due to the Hold Purchase The Land exceeding scheduled plan. In Situation Plan, the problem that Hold Purchase The Land is solved within 7 months with 14.3% of Problem Solving that conducted monthly. But in Situation Actual the problem that Hold Purchase The Land takes 10 months to be solved, which is 3 months longer. The delay in Situation Actual is due to Problem Solving of only 10% every month which is lower than expected in Situation Plan.

Table 5.6 Simulation result for procurement management process

Situation	Completion Time (Month)	Schedule Slippage (%)	Hold Purchase The Land (Month)	Problem Solving (%/Month)
Plan	8	0	7	14.3
Actual	11	42.9	10	10.0

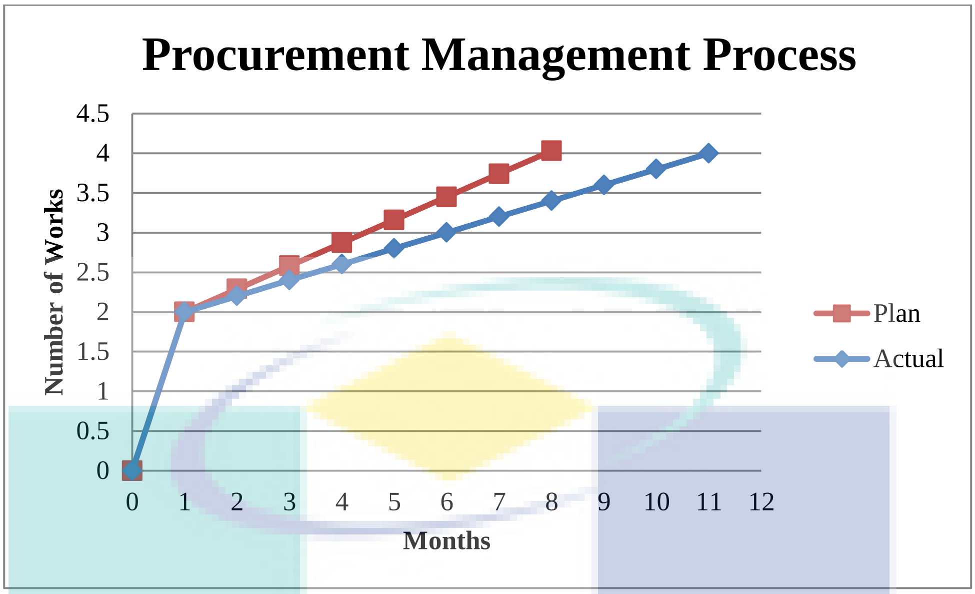

Figure 5.8 The graph of simulation result for procurement management process

5.4.2 Scope Management Process

The goal to be achieved in this scope management process is to compare between two different situations. Both situations were experimented using the simulation model under this process. The result is as in Table 5.7 and Figure 5.9.

Situation Plan represented an ideal case of which the whole process run as planned. Whereas Situation Actual represented an actual situation of scope management process. Based on Table 5.7, an estimation of 8 months period is allocated to complete this process. However, in actual condition, the time period to finish this process is 12 months which is 4 months longer with a 50% slippage from the schedule.

There are two main activities that cause this process slippage from the schedule. First is during Market Demand Survey. In the Situation Plan, the work under Market Demand Survey is targeted at 50% every month, leading a Time of Survey of within 2 months period. However, in Situation Actual, only 33.4% of work is completed under Market Demand Survey monthly, leading to a completion period of 3 months.

Another cause for this process schedule slippage is during the Project Scope Change. In the Situation Plan, the work under Project Scope Change need to undergo 16.7% of work completed every month. Only then, the Project Scope Change can be finished within 6 months through Project Review. It is different with Situation Actual, where the work under Project Scope Change reached a percentage of only 11.1% every month, causing the time to review the project to be prolonged to 9 months.

Table 5.7 Simulation result for scope management process

Situation	Completion Time (Month)	Schedule Slippage (%)	Time of Survey (Month)	Market Demand Survey (%/Month)	Project Review (Month)	Project Scope Change (%/Month)
Plan	8	0	2	50.0	6	16.7
Actual	12	50	3	33.4	9	11.1

Figure 5.9 The graph of simulation result for scope management process

5.4.3 Stakeholder Management Process

Stakeholder management process is conducted to obtain the MPK approval for the Pre Computation Plan. The simulation model for Stakeholder Management Process is experimented under different set of situations and results. The comparison between both situations and results were conducted and the details are shown in Table 5.8 and in the graph in Figure 5.10. As usual, Situation Plan is represented as the simulation result of planning and Situation Actual is represented as simulation result of actual process.

Situation Plan in Table 5.8 mentions that the Completion Time for this stakeholder management process takes 7 months whereas Situation Actual takes 8 months to complete this process. The percentage of schedule slippage between Situation Actual and Situation Plan is 14.3% with 1-month delay from schedule.

The factor causing the performance in Situation Actual to exceed the scheduled time is due to the time to rework the work error which is longer than scheduled. Work error mostly takes course once MPK asks for corrections to be made. The time allocated to complete the work error in Situation Plan is 3 months with implementation of Rework. The Rework holds a 33.5% of work every month to solve the work error. In contrast with Situation Plan, the time taken to complete the work error for Situation Actual is within 4 months with implementation of 25% of rework monthly, which is lower compared to planning.

Table 5.8 Simulation result for stakeholder management process

Situations	Completion Time (Month)	Schedule Slippage (%/Month)	Work Error (Month)	Rework (%/Month)
Plan	7	0	3	33.5
Actual	8	14.3	4	25.0

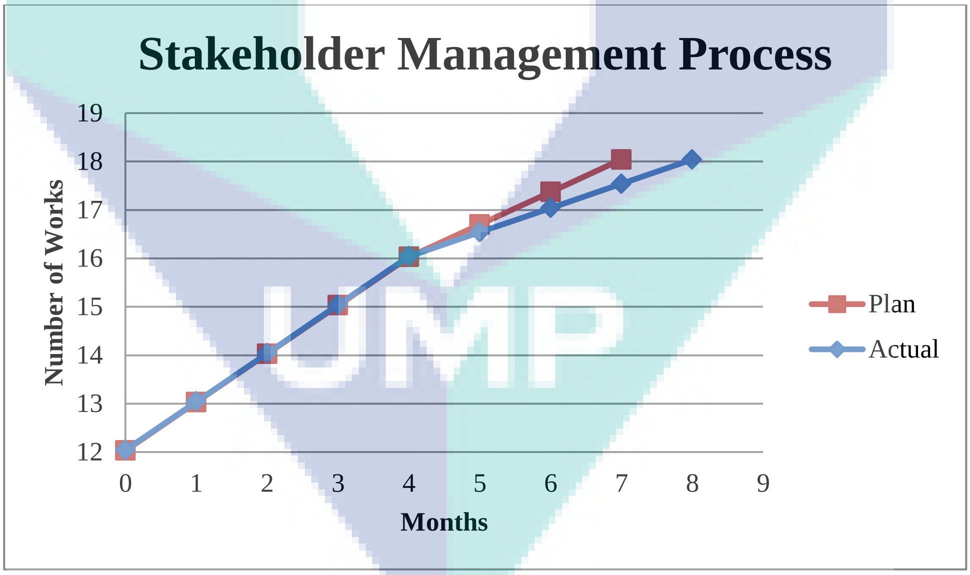

Figure 5.10 The graph of simulation result for stakeholder management process

5.4.4 Integrated Management Process

The purpose for the integrated management process is to combine two processes of preparing different plans in order to get approval from MPK at the same time, where these processes are conducted by different persons in charge. These plans are building plan and infrastructure plan.

Moreover, in the simulation result of integration management process, there is a need to compare between two situations experimented by simulation in this process. The two situations are as usual, Situation Plan as planned and Situation Actual as actual process. Through the comparison for both situations, it shows the performance for the actual process as compared to scheduled process. The results is presented in Table 5.9 and Figure 5.11.

In Situation Plan, the time allocated to finish the whole process is 5 months. The Situation Actual takes a completion period of 7 months, with 2 months over schedule and making the percentage of schedule slippage to 40%. Based on the Table 4, there are two main activities that contributes to schedule slippage.

The first is due to Architect and Engineer Submitting Plan exceeding the time planned. Situation Plan spends 2 months for the Architect and Engineer Submit Plan with the percentage of completion for both plans is at 50% per month. However, Situation Actual spends 3 months for the Architect and Engineer Submit Plan. It is one month late from schedule since the percentage of monthly completion for both plans is only 33.3%.

Moreover, another contribution to the schedule slippage in this process is the time taken for corrections of work error to be made. Situation Plan allocates 3 months to solve the work error through conducting rework of 33.3% every month. However, Situation Actual solves the work error in 4 months' time with a progress of 25% of rework monthly. The progress is slightly slower as compared to Situation Plan.

Table 5.9 Simulation result for integrated management process

Situations	**Completion Time (Month)**	**Schedule Slippage (%)**	**Architect and Engineer Submit Plans (Month)**	**Completion Both Plans (%/Month)**	**Work Error (Month)**	**Rework (%/Month)**
Plan	5	0	2	50	3	33.3
Actual	7	40	3	33.3	4	25.0

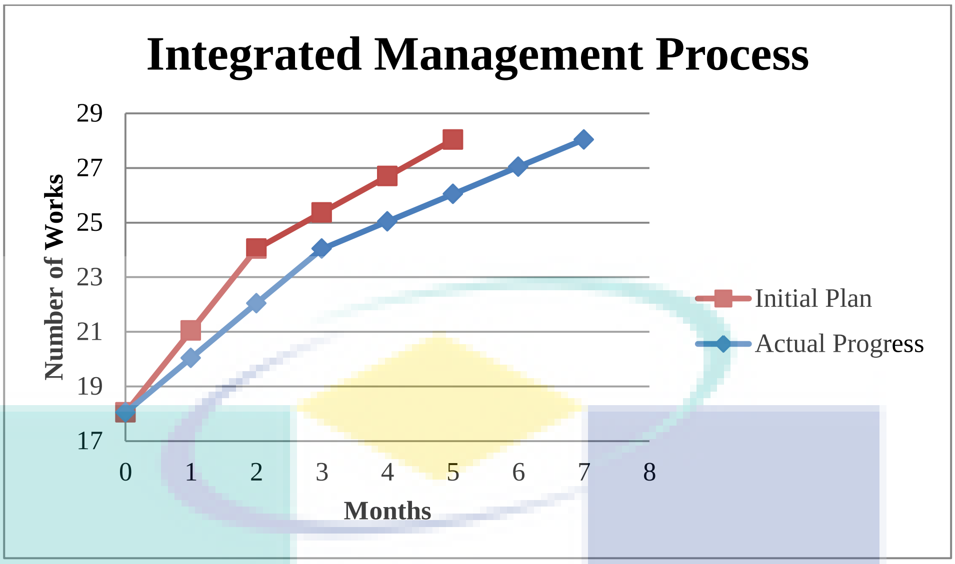

Figure 5.11 The graph of simulation result for integrated management process

5.4.5 Human Resource Management Process

The last process in pre construction project stage is human resource management process. This process is conducted to select the tender award. Likewise, the previous process, the simulation result of human resource management process is also tested for two different set of conditions. First condition is run as process planned, Situation Plan, and the second condition is set as real process, Situation Actual. The simulation result for both conditions is shown in Table 5.10 and Figure 5.12.

According to Table 5.10, the time taken to complete the process in Situation Plan is 3 months. However, in Situation Actual, it takes an extra 1 month to complete this process, holding a schedule slippage of 33.3% for this process.

The delay of QS Submit Tender's Scope reduces the performance of this process. As plan, Quantity Surveyor (QS) need to submit the tender's scope within 1 month with a completion rate of 100% in the first month. However, in the actual process, QS Submit Tender's Scope in 2 months time with only 50% of tender's scope completed at the first month.

Table 5.10 Simulation result for human resource management process

Situations	Completion Time (Month)	Schedule Slippage (%)	QS Submit Tender's Scope (Month)	Tender's Scope (%/Month)
Plan	3	0	1	100
Actual	4	33.3	2	50

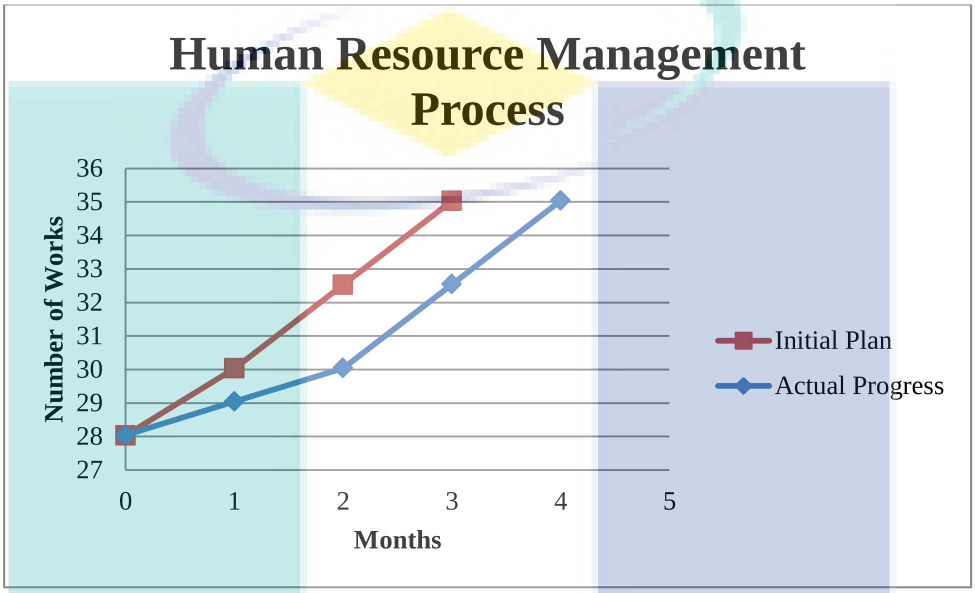

Figure 5.12 The graph of simulation result for human resource management process

5.4.6 The Pre Construction Project Stage Processes Performance

After all the simulation results for each knowledge area of sub model are explained, then the complete simulation result is developed. This result is combined with all simulation results after each the simulation process have completed its process, which are procurement management process, scope management process, stakeholder management process, integrated management result, and human resource management process.

Figure 5.13 shows the complete simulation results of actual progress and initial plan in pre construction project stage for each process. This graph is aimed to compare between actual progress with initial planning. This comparison is conducted to see the project performance in pre construction project stage. From the graph, the actual progress in this pre construction project stage is over the schedule for 12 months. The delay for each process is shows in Table 5.11. Scope management process is the highest process that contribute to project delay and stakeholder and human resource management processes are the lowest process that contributes to project delay.

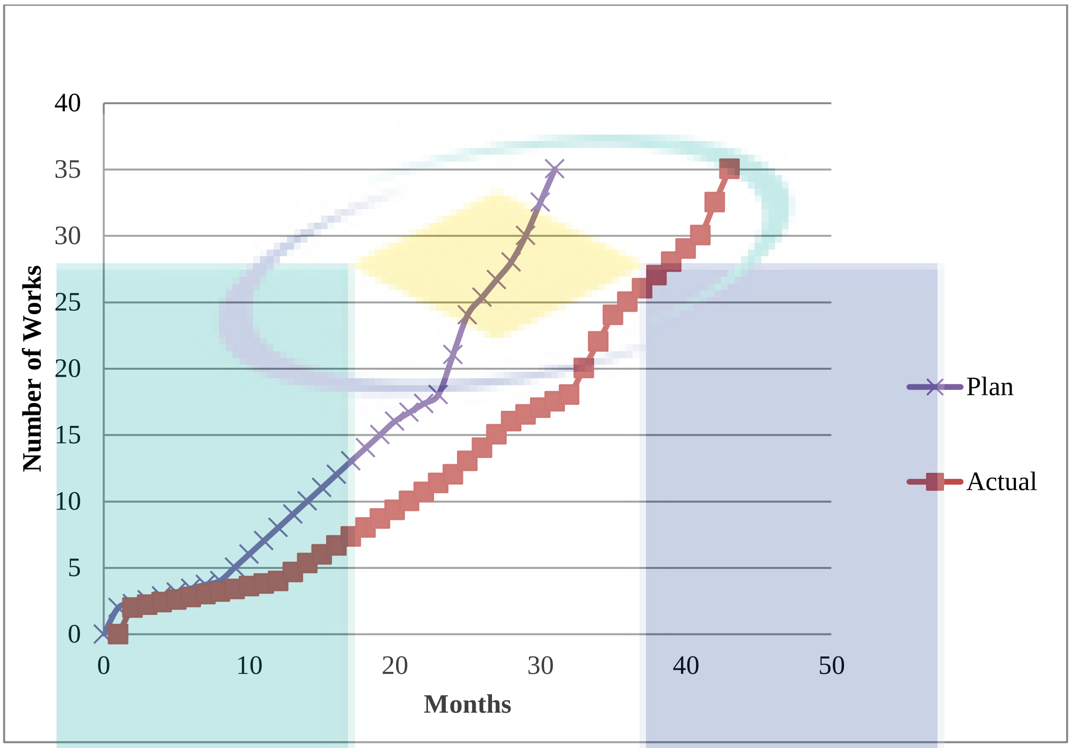

Figure 5.13 The performance of pre construction project stage

Table 5.11 Delay for each process in pre construction project stage

Knowledge areas process	Process Planned (Month)	Actual Process (Month)	Delay (Month)
Procurement Management	8	11	3
Scope Management	8	12	4
Stakeholder Management	7	8	1
Integrated Management	5	7	3
Human Resource Management	3	4	1
Complete process	31	42	12

Although the factor that causes the project to be over scheduled is almost from all the knowledge areas, but each knowledge area is interrelated. There is no need to change all the knowledge areas in order to improve the pre construction project stage performance. It is because if one knowledge area is improved, it is possible to improve the other knowledge areas collectively. Therefore, this system dynamics simulation model will recommend a strategy implication based on the interconnectivity and interrelationship between project management knowledge areas in this study. This strategy will be recommended in the next section after validating this stock and flow diagram.

5.5 Policy Recommendation

The purpose of this study is to develop a system dynamics model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK, which is already developed in Figure 5.1. After achieving the simulation results and conducting certain validation tests, this system dynamics model is valid to use in order to make a recommendation of strategy implication based on the interconnectivity and interrelationship between project management knowledge areas.

Strategy or policy is a suggestion to improve the existing process and to assist in the decision making process. This suggestion comes out with a variable relationship in the model and also from the simulation results. After getting the simulation result and comparing with the actual project, it has shown that the project suffers with time delay. Therefore, the policy that has been formed could help in reducing the time delay.

Normally, projects very rarely, go as planned. However, there are some measures that project managers can do to avoid schedule overrun. If the problem is looked at in a bigger view, it can be seen that there is a suitable recommendation of strategies that can be proposed to reduce the project delay. In this part, some recommendation can be suggested according to system dynamics simulation learning and simulation result in this study.

5.5.1 Integrated Management by Combining Some Activities

Before the suggestion policy is proposed, it is necessary to identify the limitation of the existing model that can be improved. The insights of the model is that the model is simulated in parallel pattern which is each knowledge area process only can be started after the previous knowledge area process is completed. This situation will result in the process to finish the pre construction project stage longer. Besides that, all the knowledge areas processes are conducted one by one.

In this system dynamics model, it seems that certain sub models are in charge of different parties. Such stakeholder management process is conducted by planner, integrated management process is controlled by architect and engineer, and human resource management process is managed by a quantity surveyor. It means some of the activities in the knowledge areas process can run individually, without waiting for other processes to be totally completed.

If these sub models are conducted with different parties, there is an opportunity to allow these models to run simultaneously, which is the use of integrated management approach. According to Demirkesen and Ozorhon (2017), a study was conducted to investigate the relationship between integration management with project performance, it was found that integration management has a major impact on project management performance. A study using a case study about application of the integrated methodology was conducted. The findings from the study prove that one of the significant benefits of integrated methodology is reducing time (Balfe et al., 2017).

Therefore, the project manager of this project suggested to use the integrated management process as one of policy suggestion to improve the project delay. After the procurement management process is completed, the scope management process begins. After scope management process finishes, this means the paperwork for the project were approved by management and then the election of consultants has been there (planner, engineer, architect, and quantity surveyor). Hence, it allows the other knowledge areas process to begin.

In order to reduce the time overrun, the stakeholder management process can be started together with some of the activities in the integrated management process and the human resource management process. It is because each knowledge areas process is conducted by different parties. Stakeholder management process is conducted by a planner, Integrated Management Process is conducted by an engineer, and Human Resource Management is conducted by a quantity surveyor.

The activities that can be run simultaneously with Stakeholder Management Process are the process to prepare plans for building and infrastructure in the Integrated Management Process and the process to prepare the tender’s scope in the Human Resource Management Process.

Figure 5.14 and Table 5.12 show the simulation result after implementing the policy suggestion compared with the simulation result before implementing policy suggestion and the initial plan. This graph explains that implementation of the Integrated Management knowledge area influences the change in Stakeholder Management Process, Integrated Management Process, Human Resource Management Process, and ultimately the entire of the Pre Construction Project Stage model.

The improvement made after implementing the policy recommendation, is the percentage schedule slippage reduces from 35.5% to 19.4%. Even, this policy recommendation cannot improve totally the time delay in this study, but this policy recommendation purpose is to prove that there are interconnectivity and interrelationship between different knowledge areas in PMBOK during the pre construction project stage. If one knowledge area changes or improves, other knowledge areas also can also change or improve.

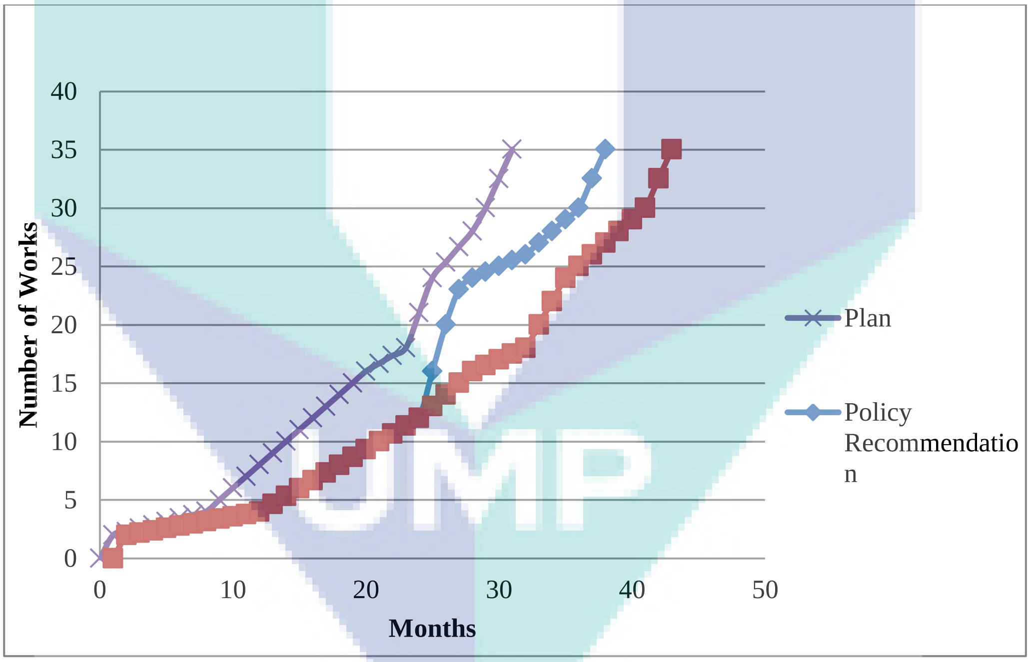

Figure 5.14 The graph of performance policy recommendation

Table 5.12 The table of performance of policy recommendation

Scenarios	Plan	Policy Recommendation	Actual
Completion Time (Month)	31	37	42
Schedule Slippage (%)	0	19.4	35.5

5.5.2 Increase The Human Resource in Certain Sub-Model

For the second suggestion, the simulation model is utilized to optimize and increase human resources in selected sub-model against the reduction of the project duration. In many cases, if the amount of workers increases, the time to complete the work becomes faster but the cost increases. However, many organizations want to optimize the human resource in order to optimize the benefit with low cost. In fact, some human resources have their limited ability in certain situations to complete the task given and need additional human resources to complete the task with additional cost.

In the real situation, this project experiences project delays and the project manager suggests to increase workers in certain processes which does not involve an increasing cost. Stated by E-Silva and Costa (2013), there are different complexities of projects such that allocating greater or lesser amount of human resources that can directly affect the time taken to complete the project. Therefore, this simulation model is developed to recommend a strategy that can reduce the project delay by optimizing and increasing human resources without increasing cost.

This strategy is conducted by increasing another worker in selected processes, but these workers are not full-time workers. Because the function of additional workers is only required to complete the work that is not able to be completed by existing workers within the allocated time. This strategy does not include additional cost because the recruitment of workers are from the consultant's teams itself. For example, an architect is recruited from a consultant's team. This consultant's team should finish the project activities provided within 3 months. However, the activities cannot finish within time provided and need extra time. The project manager has no choice but to add time. This extra time will drag the project time at the end. Therefore, this study is to suggest a strategy that can help the project manager to ensure the number of workers that are recruited by the consultant's team is suitable to finish the project on time.

However, stated by the project manager in this project, not all processes if added workers will reduce the project delay, like scope management process and stakeholder management process. It is because of the problem in these processes are not due to lack of workers. The problem is due to the scope determination of the entire project that will only involve by the management and certain parties. If workers are added, the work may get complicated and does not reduce the time. Whereas, procurement management process, integrated management process, and human resources management process are the processes that can reduce project delay by increasing workers.

The procurement management process can reduce project delay by increasing workers because in this process, there are some activities that can be divided among existing workers and additional workers. In the procurement management process, the aim of the activities is to purchase the land. However during the site visit and land survey, this can be conducted by one person from the existing workers and another one from additional workers. So there is no need for the existing workers to conduct the activities twice and able to reduce the project delay.

Moreover, integrated management process also can reduce the project delay by adding the worker. In this process, the architect needs to complete and submit the building plan. In order to submit the building plan, there are various types of building that need to be completed by the architect. If these various types of building can be divided between existing workers and additional workers, the time of completing for the whole project building plan can be speeded up. This makes the project delay to be reduced.

Addition, human resources management process is a process to recruit a contractor by preparing the tender. The process to prepare the tender take some time because that is a need to collect related documents and summarize it, in an easy way to include in tender. However, if this process can be delegated between existing workers and additional workers, the project delay can be reduced. Therefore, through the system dynamics model, it can show how much percentage of time is used by the additional worker to complete the task in order to reduce project delay and count how many months can be saved by doing that.

Based on the procurement management's stock and flow diagram in Figure 5.2, the worker who is hired is considered as the expert. This expert's function's to conduct site visit, study the land, analyse the status and cause of the problem, as well as to solve those problems that can cause delays in the process of purchasing the land. The existing expert needs almost 11 months to solve these issues. However, the project schedule plan is to finish this process within 8 months. If the number of experts plus with another one worker that also expert, it allows the time of procurement management process to purchase the land to be reduced and to achieve the time allocated.

Moreover, in order to achieve the schedule time for this process (8 months), the additional experts need to complete the work faster and save 3 months. Therefore, using the simulation model, it's able to show how much is the percentage of work that is needed to be completed by additional expert and how much time could be saved. As shown in a graph in Figure 5.15, if the additional expert is able to solve 10% or 20% of the entire works, the time can be saved for 1 month or 2 months, which are from 11 months it becomes 10 months or 9 months. However, if the works are carried out with 30% by additional expert, then the time will be reduced in three months. It means this process has achieved the time goal to finish the process within 8 months.

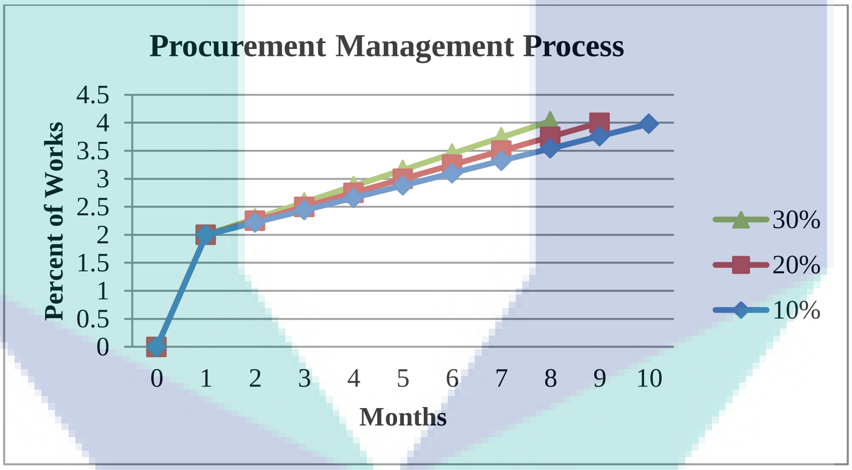

Figure 5.15 Procurement management process after increased the worker

After the procurement management process, the next is the scope management process and followed by stakeholder management process. However, both processes have no change in the implementation of this strategy. The next process is integrated management process. During the integrated management process, the human resources that are related in this process are an architect and an engineer. Based on stock and flow diagram in Figure 5.5, architect and engineer should prepare 2 documents to submit to MPK, which are building plan and infrastructure plan. After that, both architect and engineer need to make corrections after review by MPK. The actual duration that is used in this process is within 7 months, which is 2 months delay from the expected duration.

In order to achieve the expected time to finish this process, another one of part-time worker is needed. According to Figure 5.16, if the percentage of works is finished by the part-time worker is 20% or 30%, the estimated time for completing this process is reduced but do not achieve the target, which is 6 months. Unless the part-time worker increases the percentage of works to finish by 40%, only then this process can finish the work at the right time, within 5 months.

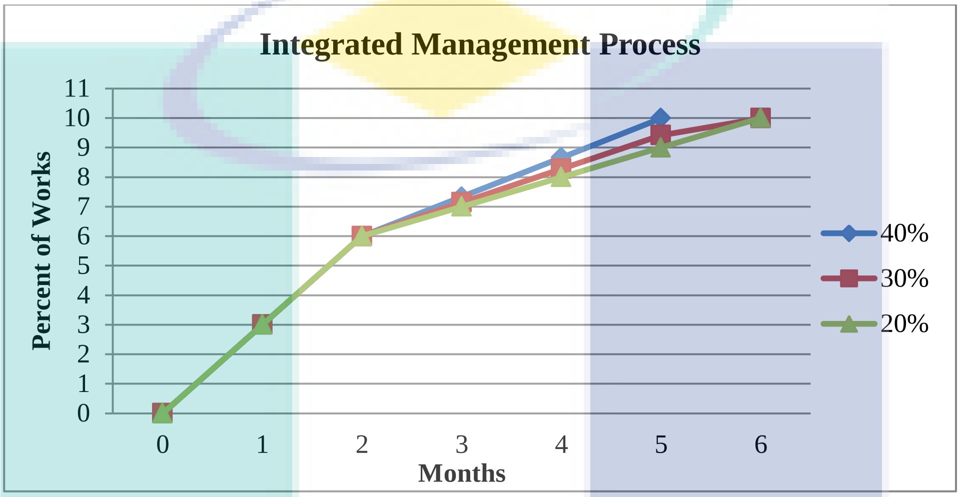

Figure 5.16 Integrated management process after increased the worker

In the last process, which is the human resource management process. The worker who is related in this process is a quantity surveyor. As in Figure 5.6, the quantity surveyor should prepare the scope of the tender documentation. After the tender documentation is completed, then the advertisement to call contractor is conducted. The actual time to finish this process is about 4 months and the estimated time to finish this process is 3 months.

In order to finish this process at the estimated time, this process should include one additional worker to accelerate works completed. According to Figure 5.17, if the works in this process is completed with 30% or 40% by the additional worker, it means the completed time is still same as the previous. The only way to finish this process within 3 months is that the additional worker should complete 50% of work.

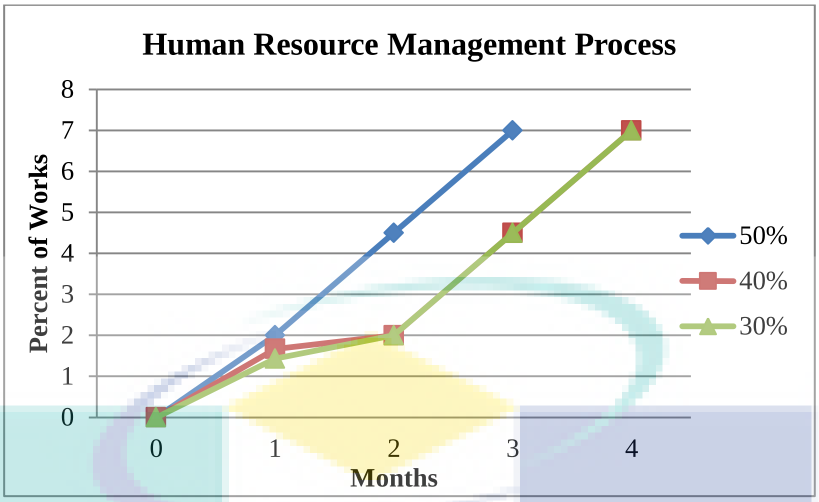

Figure 5.17 Human resource management process after increased the worker

After running all the simulation model processes related, the result for the whole processes are shown as in Table 5.13. In order to run each knowledge areas process similar as the schedule of the project, additional human resources are required. From the Table 5.13, shows that the additional worker in procurement management process needed to work 30% , additional worker in integrated management process need to work 40%, and additional worker in human resources management process need to work 50% in order to complete these three processes as schedule. If these three processes are completed as schedule, the whole processes have reduced of 54.5% of project delay with 6 months from delay saved.

From this suggestion policy, it can help the project manager to ensure the number of worker that are recruited by each consultant's team is suitable to finish the project on time. Simulation model makes easy for managers to see and to choose the convincing decision for the decision-making. This result indicated the existing of the interconnectivity and interrelationship between different knowledge areas and the changes in one knowledge area, which is human resource knowledge area can lead the change to another knowledge area too.

Table 5.13 The result of increasing human resources for all sub-models

Sub-model of knowledge areas	**Schedule (Month)**	**Percent of works done by additional worker (Month)**						**Actual (Month)**
		50 (%)	**40 (%)**	**30 (%)**	**25 (%)**	**20 (%)**	**10 (%)**	
Procurement management process	8	8	8	**8**	9	9	10	11
Scope management process	8	12	12	12	12	12	12	12
Stakeholder management process	7	8	8	8	8	8	8	8
Integrated management process	5	5	5	6	6	6	7	7
Human resource management process	3	3	4	4	4	4	4	4
Total Duration	31	36	37	38	39	39	41	42

5.6 Summary

During conducting this study, the second and third objectives of study were achieved, which are:

1) To develop a system dynamics model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK.

2) To make recommendations of strategy implication based on the interconnectivity and the interrelationship between project management knowledge areas.

The second objective is achieved during the development the stock and flow diagram and translates the information from the causal loop diagram into the stock and flow diagram. The third objective which is the last objective in this study achieved during conducting policy recommendation.

As a summary, this system dynamics model has shown that there is interconnectivity and interrelationship between different knowledge areas in PMBOK in a pre construction project. It is also important to see the different knowledge areas in the project is not as separate, especially while in decision making because each knowledge area is interrelated among them. If a change is made in one knowledge area, it is highly probable to cause the change in other knowledge areas and ultimately the overall process. Therefore, it is a requirement for project manager to know, which knowledge areas is suitable to improve in the project in order to solve the problem.

CHAPTER 6

CONCLUSION

6.1 Introduction

The last chapter is for the conclusion for this study. This chapter begins with the conclusion about the findings of this study in brief. After that, the limitations of this study is presented, then followed by the recommendation for the future research. Lastly, the conclusion of this chapter is provided

6.2 Conclusion

In order to ensure improved project performance, it is important to look at the factors that have led to decreasing the project performance by looking at it as a whole. These factors will lead to problematic project such as project delay. Project delay is something common in project construction. Many project managers try to find the cause of project delay in order to solve that problem with project management knowledge areas. However, some of the project managers tend to focus only certain project management knowledge areas to solve the problem, which is to look at the problem separately or one by one. This method is easier to handle and saves time, but these practices make the project manager unable see the problem as a whole.

As the result, the solution provided for the problem only can solve the problem partly and not in a holistic view. It will make the decision-making that is made to become bias. In fact, one decision that is made could influence another problem to emerge. It is because each event there must have a cause and effect, which is mutual respect. Project manager is required to have various knowledge to manage and solve the issue in the project. Therefore, Project Management Body of Knowledge (PMBOK) have come out with guidelines to provide the knowledge areas for project management.

PMBOK by Project Management Institute (PMI) introduces ten knowledge areas that is commonly used by project managers as the standard guideline for project management while building the project. It is very useful. However, the discussion in PMBOK is not enough to help the project manager to see the interconnectivity between different knowledge areas in PMBOK while managing the project in practical. Hence, the project manager requires a powerful tool that can help them to understand the interconnectivity between different knowledge areas in managing the complexity of the project construction. Therefore, the objective of this study is generated.

The first objective of this study is to identify the interconnectivity and interrelationship between different knowledge areas in PMBOK. This objective can be answered starting from the literature review from varied journals and other resources that were able to describe how some of knowledge areas have interrelationship among other knowledge areas. Then, this study used a practical case study in a construction project to define the knowledge areas that was used in the project and then developed a causal loop diagram. This causal loop diagram is developed to identify the interconnectivity and interrelationship between different knowledge areas in PMBOK.

The causal loop diagrams that is developed is shown in Chapter 4. From the causal loop diagram, it can help the reader to have a more understanding about the dynamics and the complexity of the project construction's environment of the problem with some knowledge areas that are involved. It is because the causal loop diagram can decompose the loop into smaller loop with their own purpose that is not complicated to understand and easily manageable. In addition, the causal loop diagram becomes more realistic when it is reviewed by a qualified person in the related industry and makes some modifications.

The second objective of this study is to develop a system dynamic model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK. In order to answer this objective, the stock and flow diagram using iThink software was constructed. The iThink software is a computerized simulation system that is able to construct the system dynamics model for this study. The construction of stock and flow diagram is influenced by the causal relationship that was translated from the causal loop diagram in Chapter 4. After the stock and flow diagram has already been constructed in Chaper 5, then the model is tested to get a valid model in order to make a recommendation strategies for this study.

The third as the last objective of this study is to make recommendation strategies based on the interconnectivity and interrelationship between project management knowledge areas. The purpose of this objective is to provide policy recommendations that can be used to improve existing processes that is represented by a case study in construction project during the pre construction project stage. This policy recommendation is already presented in Chapter 5.

The findings from this study is each knowledge area that is used in the pre construction project stage has the interconnectivity and interrelationship between them. If one knowledge areas is delayed, it will cause the other knowledge areas also to be delayed. During the process of recommending a decision to reduce the project delay, each knowledge area that is related is seen in the larger view and not as separate.

As the result, the strategy that is proposed in this case study can reduce that project delay with the understanding to what had happened to other knowledge areas. It is because the system dynamic model is able to show the interrelationship between different knowledge areas in this study, not separately but in collectively. If the strategy is applied to one of the knowledge areas, then it will indicate the probability of the change that occur to other knowledge areas. Nevertheless, the strategy that is applied will consider the change that happens for other knowledge areas Through this model, hopefully project manager can use to understand the behavior of the construction project situation in a larger view, in a way to define solution in any project issue that exists.

6.3 Limitation

This study has some limitations that cannot be covered at all. The first limitation appears from the limited focus field for this study. This study is focused in construction field of industry only. It shows that the outcome from this study is not suitable to be interpreted into other industries like manufacturing, because the process conducted for the activities are different. Besides, this study uses a case study in construction project as the methodology. In case study, it is related to real-life case, according to the situation that certain organizations face. The situation that the organization encounters may have some differences with other organization, even in the same industry. They involve some of the variables of interest related to certain organization only. However, mostly it does not make much difference with other organizations in the construction field.

This study is based on the project management knowledge areas in PMBOK fifth edition as the latest edition at this time. However, this book frequently changes time by time. It may be appropriate now, but will not be appropriate for the near future. Therefore, it is important to update the new edition for PMBOK in future.

6.4 Recommendations for Future Research

This study has developed a system dynamics model that can be used to simulate the interconnectivity and interrelationship between different knowledge areas in PMBOK. However, future research is needed to make the system dynamics more realistic.

In this study, the system dynamics simulation model is used to identify the interrelationship and interconnectivity between different knowledge areas in PMBOK. However, this study does not capture all the ten knowledge areas in PMBOK during the system dynamics simulation model development. The knowledge areas that are included are procurement management, scope management, stakeholder management, integrated management, and human resource management. Therefore, future research should take into account the other knowledge areas that are not covered by this study.

An additional suggestion for future research, the research should be done for other situation of case study even in the same industry. In construction projects, there are three main stages in conducting the construction project activities, which are pre construction project stage, construction project stage, and post construction project stage. This study covers the first stage in the construction project that is the pre construction project stage. Therefore, future research should look into the different stages that are involved in construction projects.

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APPENDIX A
PELIMINARY PROCESS

No	Activities of the project	Schedule time	Actual time
1	**Site visits**	**8 months**	**11 months**
1.1	Site visit (the suitability of land for development)	0.5	0.5
1.2	Study the land (Suitability, location, and condition of the land)	0.5	0.5
1.3	The process to determine the land	6	9
1.4	Meeting for product on the land	1	1
2	**Current market research**	**2 months**	**3 months**
2.1	Survey the demand of the area	1	2
2.2	Survey the demand of the building design	1	1
3	**Plan project on the land**	**4 months**	**5 months**
3.1	Appointment of consultant (surveyor)	2	2
3.2	Develop layout proposal	1	1
3.3	Prepare pre-computation proposal	1	2
4	**Paperwork**	**1 months**	**2 months**
4.1	Paperwork for planning project	1	2
4.2	Proposed budget for the project	1 - concurrent	1 - concurrent
5	**Management approval**	**1 months**	**2 months**
5.1	Approval paperwork from management	1	2
5.2	If passed, proceed next stage. If not passed, repeat steps 2-4	Info	Info

APPENDIX B
PLAN APPROVAL PROCESS

No	Activities of the project	Schedule time	Actual time
1	**Preparation of pre computation**	**4 months**	**4 months**
1.1	Appointment of consultants	1	1
1.2	Planner completes and submits the pre computation plan	3	3
1.3	Management determines the best plan	0.5 - Concurrent	0.5 - Concurrent
1.4	Submit for MPK's approval	0.5 - Concurrent	0.5 - Concurrent
2	**Approval of pre computation**	**3 months**	**4 months**
2.1	Implement amendments from MPK	1	2
2.2	MPK approval	2	2
3	**Preparation of building plan**	**2 months**	**3 months**
3.1	Architect completes and submits the building plan	2	3
3.2	Management determines the best plan	0.5 - Concurrent	0.5 - Concurrent
3.3	Submit for MPK's approval	0.5 - Concurrent	0.5 - Concurrent
4	**Approval of building plans**	**3 months**	**4 months**
4.1	Implement amendments from MPK	1	2
4.2	MPK approval	2	2
5	**Preparation of infrastructure plan**	**2 months – concurrent with building plan**	**3 months - concurrent with building plan**
5.1	Engineer completes and submits the infrastructure plan	2	3
5.2	Management determines the best plan	0.5 - Concurrent	0.5 - Concurrent
5.3	Submit for MPK's approval	0.5 - Concurrent	0.5 - Concurrent
6	**Approval of infrastructure plan**	**3 months – concurrent with building plan**	**4 months - concurrent with building plan**
6.1	Implement amendments from MPK	1	2
6.2	MPK approval	2	2

APPENDIX C
CONSTRUCTION TENDER PROCESS

No	Activities of the project	Schedule time	Actual time
1	**Preparation of tender**	**1 months**	**2 months**
1.1	Discussion scope of tender	0.5	1 month
1.2	Prepare tender by quantity surveyor	0.5	1 month
2	**Tender (Call & Close)**	**1 month**	**1 month**
2.1	Advertisement the tender	0.5	0.5
2.2	Accept the tender until the specified time	0.5	0.5
3	**Tender evaluation and award**	**1 month**	**1 month**
3.1	Rating the contractor qualifications	0.25	0.25
3.2	Management approval	0.5	0.5
3.3	Award tender for successful contractor	0.25	0.25