SYSTEM DYNAMICS IN PROJECT MANAGEMENT: ASSESSING THE IMPACTS OF QUALITY FAILURE ON PROJECT PERFORMANCE

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ABSTRACT

It is common in pressure vessel manufacturing to face time completion issue during fabrication process. Small and Medium Enterprise (SME) also facing this difficulties as refer to their ISO audit summary. Mainly almost 50% of the projects are delivered later than the contractual dates. Common software use to come out with time completion are Microsoft Project and Primavera. However these software do not have multi-interface relationship with other variables such as quality and rework during fabrication. Thus in this research, System Dynamics is introduced to get the optimum fabrication time for pressure vessel construction in SME industry which considering rework due to quality error. The causal loop diagram is been identified before running a rework model using Stella software. The input of the task is obtained via the current project schedule of one of the SME company in Pahang, Malaysia. In result and discussion, the duration time for fabrication is obtained when rework is considered during fabrication. By using System Dynamics approach, more variables can have their multi-relation effect which can better forecast and estimate the time of completion.

ABSTRAK

Di dalam industri pembuatan pengandung tekanan tak berapi (PTTB) selalu terjadi masalah untuk menyiapkan kerja dalam tempoh yang ditetapkan. Ini juga terjadi di kalangan usahawan-usahawan Industri Kecil dan Sederhana (IKS). Mengikut salah satu laporan audit ISO syarikat IKS, lebih 50% daripada projek yang dijalankan mengalami kelewatan dalam menyiapkan tugasan. Microsoft Project dan Primavera adalah antara perisian yang biasa digunakan untuk menentukan berapa hari yang perlu bagi menyiapkan kerje fabrikasi. Walau bagaimanapun perisian ini adalah terhad untuk menghubungkaitkan pelbagai pemboleh ubah seperti kualiti kerja dan proses "rework" semasa proses pembuatan. Oleh itu dalam kajian ini, Sistem Dinamik telah digunakan untuk mengetahui masa optimum fabrikasi pembinaan PTTB di dalam IKS di mana "rework" yang disebabkan oleh masalah kualiti dipertimbangkan. Satu Rajah Gelung Sebab dan Akibat (Causal Loop Diagram) telah dikenal pasti sebelum melakukan Rajah "Stock and Flow" menggunakan perisian Stella. Input untuk Sistem Dinamik ini diambil melalui salah satu projek syarikat fabrikasi PTTB di Pahang, Malaysia. Di dalam bahagian keputusan dan perbincangan, tempoh masa yang diperoleh untuk menyiapkan fabrikasi adalah dengan mengambil kira "rework". Dengan menggunakan kaedah Sistem Dinamik, pembolehubah-pembolehubah boleh mempunyai banyak hubungan bagi menambah baikkan teknik meramal dan menganggarkan tempoh menyiapkan proses fabrikasi.

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LIST OF ABBREVIATION

TGAST	Terengganu Gas Terminal
CPM	Construction Project Management
CLD	Causal Loop diagrams
CL	Causal Loop
DES	Discrete Event System
DPT	Dye penetration testing
EPCC	Engineering, Procurement, Construction and Commissioning
LD	Liquidity Damage
MPI	Magnetic particle testing
RT	Radiographic testing
SAT	Site Acceptance Test
SF	Stock and Flow
SD	System Dynamics
SME	Small Medium Industries
UT	Ultrasonic testing
WBS	Work Breakdown Structure

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CHAPTER 1

INTRODUCTION

1.1 Introduction

his chapter provides an in detail analysis on the background of the study, statement of the problem, project objective and a scope and limitation of the project. The organisation of the thesis briefly explained before a conclusion is provided at the end of the chapter.

1.2 Background of the Problem

PProject management is arguably one of the most important and poorly understood areas of management (Sterman, 1992). Sterman (1992) described that delays and cost overruns are synonyms in construction, defense, power generation, aerospace, product development, software, and others areas. Project management suffers from various problems of cost and scheduling (Sterman, 1992). As referred to by Park and Pena-Mora (2003), schedule delays and cost overruns have frequently continued in construction projects despite advances in construction equipment and management techniques. A customer's design changes and quality failures are frequent, impacting the overall cost which creates delays and disruption throughout the entire organisation (Park and Pena-Mora, 2003).

The consequences include poor profitability, loss of market share and reputation, increase turnover of management and workforce, lower productivity, higher cost and, all too frequently, disruptive and costly litigation between customers and contractors over responsibility for overruns and delays (Sterman, 1992).

Construction is wide-angle business in Malaysian Industries. It consists of the construction of high rise buildings, offices, factories, airports and also refineries for oil & gas such as Oleo chemical or by-product refinery. Some samples of existing Oil & Gas projects like Kebabangan Offshore Platform and Rapid On-shore Refinery includes fabrication work for pressure vessels, piping and structure. All this construction work will be evaluated in terms of their performances which are delivery, client satisfaction and company profits/losses including revenue. One of the performance measures in construction work, delay, is defined as 'late completion of the project against the Purchase Order, PO contractual date and planned schedule'. As mentioned by Dinakar (2014) construction delays often result from miscommunication between contractors, subcontractors, owners, and suppliers. Delays in construction projects result very expensive for all parties involved.

Oil and Gas businesses provide one of the major contributions to the Malaysian economy. Plenty of platforms and Petrochemicals plants have been built or expanded to cater to the need. Expanded plants or newly built plants come with new technologies to maximize the use of crude oil by producing a variety of by-products that can minimize waste. Malaysian Oil and Gas industries are categorised into 2 main sectors: Upstream and Downstream. The Upstream sectors involve Exploration and Production (E&P) mainly at off-shores, this also involves geologists searching or measuring and producing crude oil and natural gas.

TExamples of Upstream sectors in Malaysia are the Kikeh Platform and Kebabangan platform. Meanwhile, the downstream process, which is mainly on-shore, consists of processing and converting crude oil into petrol, diesel and other products and then selling those products to customers. With specific brands and technologies, the Downstream industries offer thousands of varieties of products for users/customers around the globe. The products most familiar in markets are gasoline, diesel, jet fuel, heating oil, asphalt for roads, lubricants, synthetic rubber, plastics, fertilizers, and pesticides produced or manufactured by Petronas, ExxonMobil, Shell, and DOW Chemical. Table 1.1 shows and differentiates the activities of Upstream and Downstream sectors of oil and gas.

Malaysian construction related to Oil and Gas refineries or offshore platforms are divided into two categories, Green and Brown field. Brownfield refers to an existing onshore or offshore facility undergoing modifications or replacements to an existing facility, while the Greenfield project refers to a new field development requiring new facilities, either onshore or offshore. Existing projects in Malaysia such as the Terengganu Gas Terminal, (TGAST) project developing in Terengganu and the RAPID project in Johor are considered Greenfield projects while ExxonMobil Tapis/Teluk ToR Platform Rejunivation are considered to be Brownfield projects. The mentioned Greenfield project belongs to PETRONAS who awarded the Engineering, Procurement, Construction and Commissioning (EPCC) contract to the selected vendor with a contractually agreed on completion date. For example, the TGAST project was fully awarded to the Korea construction company (Samsung Engineering Co. Ltd.) as the turnkey contract covered the EPCC and was expected to be completed in June 2016.

The EPCC contractor is responsible for producing main designs including engineering details of the project, procures all the equipment and materials, construction and Site Acceptance Test (SAT) to deliver a functioning facility or asset to PETRONAS. For example equipment such as pressure vessels, membrane skids, heat exchangers and piping spools for a new plant.

Table 1.1: Activities of upstream and downstream of oil and gas.

Oil & Gas Field	Activities	Description
UP-Stream	Field Exploration, Development & Production	All petroleum resources of Malaysia are regulated by Petroleum Management Unit, PETRONAS through Petroleum Development Act 1995.
		Petronas enters into Product Sharing Contract (PSC) with other petroleum companies to explore and develop resources; there are about 70 PSC contractures in Malaysia. PSC contractors in Malaysia including Petronas Carigali (OCSB), Esso Production Malaysia, Shell Sabah Selatan, Lundin Malaysia, Sarawak Shell Berhad, Sante Fe Energy, Nippon Oil, Amareda Hess, Murphy Sarawak, Mobil, JAPEX, NORSK Hydro, Mitsubushi Corp, Petrofac, Newfield's, Talisman ConocoPhillips, are among the major players.
		Method of Statement
		i) These players normally require a massive investment for the development and production activities; and raisin the capital ca bee a bit challenge
		ii) As debt finance usually depends on guaranteed revenue, it is only considered as a funding option once reserves as proven and production has commenced.
		iii) Therefore, equity finance is usually the most viable option of funding due to the inherent risk associated with drilling and exploration activities.

Down-Stream	Terminal/ Regasification	Activities range from refining and processing to marketing and trading of end products such as gasoline, jet fuel and diesel.
		There are two major integrated petrochemical zones established in Kerteh Terengganu and Gebeng Pahang; and have attracted foreign investments mainly from the USA (Doa Chemical) Germany (BASF) and Idemitsu, complementing investments from PETRONAS.
		Besides PETRONAS, there are also other refineries operated by Shell and Exxon Mobile.
		<u>Method of investment</u>
		i) This sector has been dominated by oil majors both as project sponsors and as operator, therefore their experience, page balance sheets and access to markets allow them to underpin construction and off take large financing undertakings.
		ii) However, there are also new and significantly smaller entrants which lack of track record and financial strength and face tremendous challenge in mobilizing financing.

It is required to estimate the time to Procure all the equipment to start commissioning, including the overall start-up commissioning after the equipment for the plant or unit is installed completely. Delaying the equipment completion and commissioning start- up date would impact costs of the buyer. Major impacts occur when the plant fails to run as per the designated date, there is no productivity, the cost increases and profit targets are not achieved. Even though only one part may be delayed, it could create a major impact on the overall planning and scheduling of the plant. When noticing potential impacts, clients could start to push the vendor to deliver the equipment as quickly as possible which can result in poor quality and jeopardize the safety of the plants. Working quickly will increase the percentage of error, poor planning and a lack of a good back up or contingency plan could result in a loose project management control. In the end company will suffer large amounts of back charge from the client, extra costs for the rectification work, unachieved profit targets, and negative company reputation. A project process control plan is very important in order to ensure its success. This situation does not apply to only small items, however it does cover a small range of equipments fabricated for the complex design structure, piping and pressure vessel.

However, it does depend on the size and the complexity of the vessel design, where the fabrication of the pressure vessel is not fixed. In general vessel fabrication will normally take 6 to 10 months to be completed and in some cases take longer due to the lack of availability of raw materials. With this time frame, project teams need to plan the work accordingly. Cut-off completion dates will be based on the contractual date; by working a schedule backwards, the project team can add in the time required for the procurement process, fabrication and inspection until it is ready for delivery. Nevertheless, it is easier to put a due date on a project than ensure that the task is complete on time; this occurs frequently in fabrication companies. It is common if projects do not run as smoothly as planned and the contractual date is not achieved. Table 1.2 is an example taken from a company in Pahang, Malaysia.

Table 1.2: Delivered project in company x January-June 2015

NO	PROJECT NO	PROJECT DESCRIPTION	DELIVERY	
			ACTUAL	SLIPPAGE
1	P667	SUPPLY AND DELIVERY 4UNITS OF TEST SEPARATOR	/	/
2	P677	SUPPLY OF ONE UNIT TUBE BUNDLE		/
3	P678	SUPPLY AND ASSEMBLY OF STRUCTURE SKID COARSE FILTERS FOR WATER INJECTION FACILITIES		/
4	P680	SUPPLY OF FOUR UNITS HEATER CASING		/
5	P681	SUPPLY OF ONE UNIT TUBE BUNDLE	/	
6	P684	SUPPLY OF ONE UNIT HEAT EXCHANGER		/
7	P691	SUPPLY OF GUARD BED VESSEL		/
8	P693	SUPPLY & FABRICATE SEMI ELLIPTICAL HEAD	/	
9	P697	RETUBING TWO UNITS OF TUBE BUNDLE	/	
10	P698	SUPPLY OF ONE UNIT TUBE BUNDLE	/	

The table shows the list of projects delivered in 2015. 5 projects that did not meet the contractual delivery date. The delayed projects were a result of many factors which are delays in the arrival of materials, design errors and poor workmanship.

1.3 Problem Statement

As referenced in the ISO 9001:2008 report written by one of the fabrication companies, most of the projects in 2014 were delayed by 50% from actual delivery dates. The consequences of a project delay will contribute to the Liquidity Damage (LD) of the company as stated in the contract and purchase order. The client has the right to impose the LD up to a maximum of 10% of the project's total value. During the interviewing session with the project manager of the company, the client will impose the LD by more than RM1 million due to late deliveries. However, the client may also decide to not impose LD costs even when the project was delayed. Whether the LD was imposed or not the reputation of the company and its performance, capital and profit are all damaged. Clients may lose confidence in the company to fabricate their products which leads to the loss of jobs. Thus, a dedicated project team, together with top management, need to seriously look at meeting deadlines during the fabrication of said products, as well as, meeting the quality within the budgeted cost. Referring to the report, some reasons were given for the delay in delivery. One of the reasons involves the poor quality of work that needed fixing. Thus, the statement given by Park and Pena-Mora (2003) regarding the quality failure as a factor that can frequently create delays in project management is true. Therefore, further studies to forecast the remaining time until completion when reworking is necessary needs to be developed.

1.4 Objectives

he objective of this project is to propose and develop a System Dynamics (SD) model that will give an optimum estimation time of completion. The SD model is developed to estimate the duration of pressure vessel fabrication if and/or when the quality is poor or needs reworking during the process. The pressure vessel fabrication will only cover Malaysia industries.

1.5 Research Question

The research question for this project is "What is the appropriate System Dynamics model that will provide a good prediction for the optimum completion time in pressure vessel manufacturing?" This research question is a guideline for activities that need to be completed in order to achieve the objective of the study.

1.6 Scope and Key Assumptions

This project is limited to the study of quality failure or errors in the pressure vessel manufacturing that impact the project performance for Small Medium Industries (SME) only. The Focus is solely on the failure of workmanship and rejected results from testing processes such as the Radiography and Ultrasonic testing in pressure vessel fabrication. Environmental effects and safety regulations will not be covered in this project. The project data will also only cover a Malaysian Fabricator. This study will be limited to consider the relationship of internal factors only.

1.7 Significance of the Study

By completing this project, a further understanding of using SD in a simulation process will be more promising in finding a solution for non-linear relationships. The fabrication process of the pressure vessel will be better understood to develop the simulation model when quality becomes the main issue. The model can be implemented in SME companies in order to predict the optimum delivery time. The companies can predict early on the consequences and optimum delivery time when certain problems occur during or before the projects run.

1.8 Thesis Organisation

Figure 1.1 shows the organisation of this project. It will have 5 main chapters consisting of:

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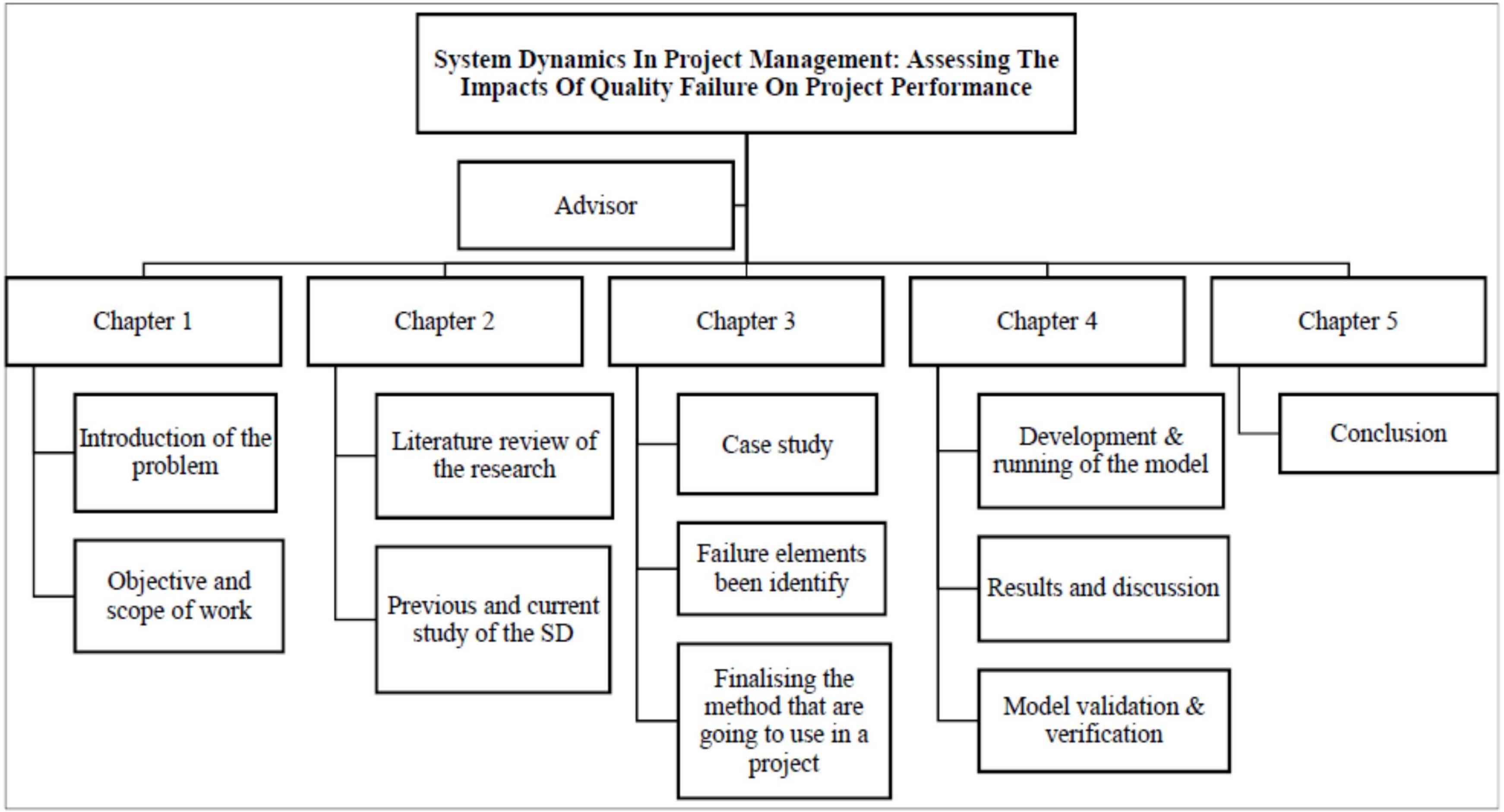
i. Chapter 1 - Introduction
ii. Chapter 2 – Literature Review
iii. Chapter 3 - Methodology
iv. Chapter 4 – Analysis, Result and Discussion and;
v. Chapter 5 – Conclusion and Recommendation

The objective, research question, significance and scope of study were described in the Introduction. In the Literature Review of the SD modelling including the application to project management will be discussed in more detail. In addition, the project management issue will also be discussed in Chapter 2. While Chapter 3 will be more focused on sequencing the research activities, including expected results, to meet the objective.

Figure 1.1: Thesis organization



Results in Chapter 4 will be validated to verify that the model is useful and can be applied in Malaysia SME industries. Improvements of the SD model and recommendations for future study will be further discussed in Chapter 5.

1.9 Conclusion

This project is about the development of an SD implementation to improve project management. An SD model was chosen to assess the impact of quality failure on project management in context of oil and gas fabrication industries. In the next chapter, project management issues are discussed, follow by a definition of the SD and an analysis of the current research regarding its application in project management.

REFERENCE

Andreas Gro¨ßler (2010). An Exploratory System Dynamics Model of Strategic Capabilities in Manufacturing. Journal of Manufacturing Technology Management Vol. 21 No. 6, 2010 pp. 651-669.

Annual Report 2011 Report on Malaysia Oil and Gas Exploration and Production, Bank Pembangunan, http://www.bpmb.com.my/gui/pdf/annual_report/2011/20.pdf

Alexandre Rodrigues and John Bowers (1996). System Dynamics In Project Management: A Comparative Analysis with Traditional Methods. System Dynamics Review Vol. 12, no. 2, (Summer 1996): 121-139

Alexandra G. Rodrigues and Terry M Williams (1998). System Dynamics in Project Management: Assessing the impact of Client Behaviour on project Performance. Journal of the Operational Research Society, Vol 49 (1) (1998) 2–15.

Boateng, P1, Chen, Z2, and Ogunlana, S. (2012). A Conceptual System Dynamic Model to Describe the Impacts of Critical Weather Conditions in Megaproject. Construction Journal of Construction Project Management and Innovation Vol. 2 (1): 208 - 224, 2012,]

Braj Kishor Mahato Stephen O. Ogunlana, (2011),"Conflict Dynamics in A Dam Construction Project: A Case Study", Built Environment Project and Asset Management, Vol. 1 Iss 2 pp. 176 – 194

Christopher Deo, Hillside (2013) "Method and System for Dynamic Project Management and Capacity Management", United States Patent

Cunbin Li, Gongshu Lu and Peng Li (2013). Risk Element Transmission Model of Construction Project Chain Based on System Dynamic, Research Journal of Applied Sciences, Engineering and Technology 5(4): 1407-1412, 2013

Farnad Nasirzadeh, Pouya Nojedehi (2013). Dynamic Modeling of Labor Productivity in Construction Projects. *International Journal of Project Management* 31 (2013) 903–911

Federico Cosenz, Lidia Not (2015). Combining System Dynamics Modelling and Management Control Systems to Support Strategic Learning Processes in SMEs: A Dynamic Performance Management Approach. *J Manag Control* (2015) 26:225–248

Hani Alzraiee, Tarek Zayed, Osama Moselhi (2015). Dynamic Planning Of Construction Activities Using Hybrid Simulation. *Automation in Construction* 49 (2015) 176–192

Hongping Yuan, Abdol R. Chini, Yujie Lu, Liyin Shen (2012). A Dynamic Model for Assessing the Effects of Management Strategies on the Reduction of Construction and Demolition Waste. *Waste Management* 32 (2012) 521–531.

J.L. Hao, M.J. Hills and T. Huang (2010). A Simulation Model Using System Dynamic Method for Construction and Demolition Waste Management in Hong Kong. *Construction Innovation* Vol. 7 No. 1, 2007 pp. 7-21

J. M. Lyneis and D. N. Ford (2007). System Dynamics Applied to Project Management: Survey, Assessment, and Directions for Future Research. *System Dynamics Review* Vol. 23, No. 2/3, (Summer/Fall 2007): 157–189

K. Yaghootkar, N. Gil (2012). The Effects of Schedule-Driven Project Management in Multi-Project Environments. *International Journal of Project Management* 30 (2012) 127–140

Michael Toole (2005) A Project Management Causal Loop Diagram", Article, *Accepted for the 2005 ARCOM Conference,* London, UK, Sep 5-7.

Michael J. Mawdesley Saad Al-Jibouri (2009). Modelling Construction Project Productivity Using Systems Dynamics Approach. *International Journal of Productivity and Performance Management,* Vol. 59 Iss 1 pp.18 – 36

Norman Gilkinson, Brian Dangerfield (2013). Some results from a system dynamics model of construction sector competitiveness. *Mathematical and Computer Modelling* 57 (2013) 2032–2043

James M. Lyneis, Kenneth G. Coopera and Sharon A. Elsa (2001). Strategic Management of Complex Projects: A Case Study Using System Dynamics. *System Dynamics Review* Vol. 17, No. 3, (Fall 2001): 237–260.

P.E.D. Love, G.D. Holt, L.Y. Shen, H. Li, Z. Irani (2002).Using Systems Dynamics To Better Understand Change And Rework In Construction Project Management Systems. *International Journal of Project Management* 20 (2002) 425–436

P.E.D. LOVE, P. Mandal and H.Li (1999). Determining the Causal Structure of Rework Influences In Construction *Construction Management and Economics* (119) 17, 505-517

Peter E.D Love, Purnendu Mandal, Jim Smith and Heng Li (2000). Modelling the Dynamics of Design Error Induced Rework in Construction. *Construction Management and Economics* (2000) 18, 567–574

S. Chritamara S.O. Ogunlana N.L. Bach (2002). System Dynamics Modeling Of Design and Build Construction Projects. *Construction Innovation*, Vol. 2 Iss 4 pp. 269 – 295

Saeed Moradi Farnad Nasirzadeh Farzaneh Glkohoo (2015). A Hybrid SD–DES Simulation Approach To Model Construction Projects. *Construction Innovation*, Vol. 15 Iss 1 pp. 66 - 83

Stephen D. Lisse, P.E. (2013). Applying System Dynamics for Outsourcing Naval Engineering Services. *International Journal of Engineering and Technology Research* Vol. 1, No. 5**,** June 2013, PP: 73 -86, ISSN: 2327-0349

Xiaoling Zhang, Yuzhe Wu, Liyin Shen, Martin Skitmore (2014). A Prototype System Dynamic Model for Assessing the Sustainability of Construction Projects. *International Journal of Project Management* 32 (2014) 66–76

Yan-yan CHU, Lin-jun HUANG, Qian-xi ZHANG, Dong LIANG (2014). System Dynamic Analysis on Behavior-based Safety in an LNG Enterprise", *2014 7th International Conference on Intelligent Computation Technology and Automation*

http://www.epcengineer.com/definition/132/epc-engineering-procurement-construction