A SIMULATION-BASED APPROACH FOR RECONFIGURATION OF FACILITIES LAYOUT DESIGN UNDER STOCHASTIC PRODUCT DEMANDS

ROBERT NG HOCK LEONG

MASTER OF SCIENCE IN MANUFACTURING ENGINEERING

2023

Faculty of Manufacturing Engineering

A SIMULATION-BASED APPROACH FOR RECONFIGURATION OF FACILITIES LAYOUT DESIGN UNDER STOCHASTIC PRODUCT DEMANDS

Robert Ng Hock Leong

Master of Science in Manufacturing Engineering

2023

A SIMULATION-BASED APPROACH FOR RECONFIGURATION OF FACILITIES LAYOUT DESIGN UNDER STOCHASTIC PRODUCT DEMANDS

ROBERT NG HOCK LEONG

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this thesis entitled "A Simulation-based Approach for Reconfiguration of Facilities Layout Design under Sthocastic Product Demands" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : ROBERT NG HOCK LEONG

Date : 9th January 2023

APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of the degree of Master of Science in Manufacturing Engineering.

Signature : .....

Supervisor Name : Ir. Dr.-Ing. Azrul Azwan Bin Abdul Rahman

Date : 9th January 2023

DEDICATION

This is dedicated to my beloved parents :
Ng Seng Eok and Chai Kearn Lan(demise) for their great support, pray, love and care.

Secondly, for my wife, Tan Ah Wat for her suport, love, care and pray.

Thirdly, my beloved sons:
Leonard Ng Chong Yew and Lewis Ng Chong Xiang

Fourthly, for my family:
Winston Ng, Jenny Ng and Corrina Ng

Fifthly, for my supervisor Ir. Dr.-Ing Azrul Azwan Bin Abdul Rahman for the great advice and support.

The last for my friends and all prople who shared their words of advice, encouragement, ideas, support and care from the beginning until the last during my thesis writing

ABSTRACT

Increased demand for customer-specific products, high cost and time pressure, as well as increasingly shorter product life cycles, has introduced new challenges to the manufacturing systems of the future. A factory layout is designed to obtain a physical arrangement of different entities of a facility that most economically meets the required output, in terms of both quantity and quality. An optimum and good arrangement can make the flow of the material free from any interruption and will increase the productivity. Manufacturing companies that undergo production expansion to their current facilities without careful facilities planning, would in most situations encounter many issues which could retard their overall operations. The constant changes and randomness of product demand under the stochastic demand continue to challenge production facilities to expand and consolidate their production facilities. When a transfer of production facilities to an existing plant is done without any expansion of current facilities, the reduced space at this plant will place a tremendous pressure on its current facilities, causing several production bottlenecks and impacting productivity. The aim of this study was to developed a systematic integrated approach to re-configure its current layout to an optimum layout under this stochastic product demand. The development of this integrated approach takes into consideration combining three key methodologies of the production optimization into a process flowchart, which are the Systematic Layout Planning (SLP), Theory of Constraint (TOC), and Discrete Event Simulation (DES). These 3 methodologies were selected based on their individual strength for the specific task required in developing this integrated approach. SLP for its sytematic layout planning, TOC to identify and eliminate constraint along the production flow and simulation to identify the optimun productive alternative layout virtually, before any physical implemetation. The steps of developing the alternative layouts are an integration of SLP with the TOC. The translated layouts were then validated by comparing the AS-IS layout with the alternative layouts and analyzed with the DES for the optimum layout in terms of productivity. The results from the case study reveal which of the alternative layout in the case, option 2 that developed through this integrated approach was the optimum layout. The throughput per hour of option 2 is improved by 15% over the existing layout and by 23% over the option 1 layout. Total distance covered for the forklift movement, with option 2 shows a much lower distance traveled than the other 2 layouts. This study reveals, the effectiveness of the developed integrated approach in developing the optimized layout with better material flow strategy.

PENDEKATAN BERASASKAN SIMULASI UNTUK KONFIGURASI SEMULA TERHADAP REKA BENTUK SUSUN ATUR KEMUDAHAN DI BAWAH PERMINTAAN PRODUK STOKASTIK

ABSTRAK

Peningkatan permintaan untuk produk khusus pelanggan, tekanan kos dan waktu yang tinggi, serta kitaran hayat produk yang semakin pendek, telah memperkenalkan cabaran baru kepada sistem pembuatan di masa depan. Susun atur kilang dirancang untuk mendapatkan susunan fizikal dari pelbagai entiti fasiliti yang paling ekonomik dan memenuhi output yang diperlukan, dari segi kuantiti dan kualiti. Susun atur yang optimum dan baik dapat menjadikan aliran bahan bebas dari sebarang gangguan dan akan meningkatkan produktiviti. Syarikat pembuatan yang mengalami pengembangan pengeluaran tanpa perancangan fasiliti yang teliti, dalam kebanyakan situasi akan menghadapi banyak masalah yang akan melambat operasi mereka secara keseluruhan. Perubahan berterusan dan rawak permintaan produk di bawah permintaan stokastik terus mencabar kemudahan pengeluaran untuk mengembangkan dan menyatukan kemudahan pengeluaran mereka. Apabila pemindahan kemudahan pengeluaran ke loji sedia ada dilakukan tanpa sebarang pembesaran kemudahan semasa, ruang yang berkurangan di loji ini akan memberi tekanan yang besar pada kemudahan semasanya, menyebabkan beberapa kesesakan pengeluaran dan menjejaskan produktiviti. Tujuan kajian ini adalah untuk mengembangkan pendekatan sistematik bersepadu untuk mengkonfigurasi semula susun atur kilang kepada susun atur optimum di bawah permintaan produk stokastik ini. Pembangunan pendekatan bersepadu ini mempertimbangkan untuk menggabungkan tiga metodologi utama pengoptimuman produksi, iaitu Perancangan Susun Atur Sistematik (SLP), Teori Kekangan (TOC), dan Diskrit Simulasi (DES). Langkah-langkah mengembangkan susun atur alternatif adalah melalui penyatuan SLP dengan TOC. Susun atur yang diterjemahkan kemudian disahkan dengan membandingkan susun atur semasa dengan susun atur alternatif dan dianalisis dengan DES untuk susun atur yang optimum dari segi produktiviti. Hasil kajian kes menunjukkan susun atur alternatif, pilihan 2 yang dikembangkan melalui pendekatan bersepadu ini adalah susun atur yang optimum. Pengeluaran per jam pilihan 2 meningkat sebanyak 15% berbanding susun atur semasa, dan sebanyak 23% berbanding susun atur pilihan 1. Jumlah jarak yang diliputi untuk pergerakan kenderaan pengangkut bagi pilihan 2 juga menunjukkan jarak perjalanan jauh lebih rendah berbanding dua susun atur yang lain. Hasil kajian ini membuktikan, keberkesanan pendekatan bersepadu yang dibangunkan dalam mendapatkan konfigurasi susun atur yang dioptimumkan dengan strategi aliran bahan yang lebih baik.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank and praise my parents, especially my demise mother, for everything I received since the beginning of my life. I would like to extend my appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. My utmost appreciation goes to my main supervisor, Ir. Dr.-Ing. Azrul Azwan Bin Abdul Rahman, from the Falculty of Manufacturing, Department Robotics and Automation, Universiti Teknikal Malaysia Melaka (UTeM), who is always there to assist and constantly supported my journey. My special thanks go to Mr. Adeboye Oluwamayowa Joshua, a graduate student in the same faculty for his assistance and support in conducting the simulation process. I would also like to express my gratitude to Prym Consumer (M) Sdn Bhd, management and staff for allowing me to carry out my study at their company. Without their assistance, it would be difficult for me to complete this thesis. Last but not least, from the bottom of my heart a gratitude to my beloved wife, Tan Ah Wat, for her encouragements and who have been the pillar of strength in all my endeavors. My eternal love also to all my children, Leonard Ng Chong Yew and Lewis Ng Chong Xiang, for their patience and understanding. Finally, thank you to all the individual(s) who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ARC	-	Activity Relationship Chart
BSA	-	Buffer Storage Area
CAD	-	Computer Aided Design
CAPEX	-	Capital Expenditure
FEM	-	Finite Element Method
FG	-	Finished Goods
FPL	-	Fixed Product Layout
GA	-	Genetic Algorithms
ICT	-	Information and Communication Technologies
ISO	-	International Standard Organization
KG	-	Kilograms
MFA	-	Material Flow Analysis
MHS	-	Material Handling System
NSF	-	National Science Foundation
PCS	-	Pieces
QC	-	Quality Control
RM	-	Raw Material
SA	-	Simulated Annealing
SLP	-	Systematic Layout Process
TOC	-	Theory of Constraint
TS	-	Tabu Search
VCB	-	Vacuum Circuit Breaker
VDI	-	Verein Deutscher Ingenieure
WIP	-	Work In Progress

LIST OF PUBLICATION

Abdul Rahman, A.A., Leong, R.N.H., Adeboye, O.J., Mohamad, E., Yee, T.J. and Md Saad, M.H., 2022. An Integrated Systematic Approach for Reconfiguration of Facilities Layout in a Stochastic Product Demand. *Jordan Journal of Mechanical & Industrial Engineering*, *16*(5).

CHAPTER 1

INTRODUCTION

1.1 Background

Factory can usually be called an industrial site ground containing buildings and machinery where workers operate machinery from one product to another producing and processing goods. Factories may either manufacture goods which are discrete or continuous.

Factory layout refers to the arrangement of physical facilities such as machinery, equipment, furniture, and so on. within the factory building. It includes departments and individual's working place. The essence of factory layout is to facilitate the quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of material to the loading of the finished product. The arrangement of the manpower, materials location and material handling is also considered to ease the production processes. A factory layout is designed to meet the required output, in terms of both quantity and quality, in the most cost-efficient manner. An optimum and good arrangement can make the flow of the material free from any interruption and will increase the productivity.

Material flow analysis of a production system in the manufacturing sector is of great importance for efficiency and profitability. Material flow analysis (MFA) is a systematic assessment of the material flows and stocks within a space- and time-defined structure. It connects the sources, the pathways, and the intermediate and final sinks of a material (Brunner and Rechberger, 2016). Major acceptance of the concept of improving

material flow is one of the core challenges facing the manufacturing sector in the future. Especially when factory expansion and optimisation must be involved, which is a fundamental goal for the manufacturing industry. Material flow analysis has several advantages: reducing operational costs, streamlining material flow, increasing efficiency, increasing competitiveness, and reducing turnaround time. Vital information resulting from a material flow analysis gives the project teams the ability to make objective decisions regarding the design of a factory layout or factory expansion.

The re-layout of a factory or facility design is aimed at improving the productivity of machines, designing an effective work-flow, workers and material flow (Kovács and Kot, 2017). Re-layout for a factory is important to improve and expand the efficient manufacturing process and to meet the needs of the workers. We also see that re-layout has a significant impact in constantly fluctuating consumer demands, resulting in changes in the inventory of products, amount of output, and improvements in the manufacturing process and innovation. In the manufacturing system's real-life operation, a reduction in the system's production costs and efficiency can be achieved to a greater extent by factory re-layout design.

Analysis of the material flow and improvement of a manufacturing system by factory re-layout can be carried out through simulation using some kind of software. Over time the method of imitating the various operations involved in a real-world process or system is called simulation. First it requires an already established model when simulating a process or system. The model is the system itself, while the simulation represents system operation over time (Anonymous, 2019). Simulation is one of the engineering methods which can be used to address scale and complexity issues. In its complex behaviour it can accurately predict any manufacturing system by observing the movement and interactions of many components within the given system. It also has ease

of scalability where the effect of any potential changes in capacity plan on efficiency and cost can be measured rather than waiting until after implementation.

Computer simulation is an instrument to carry out a simulation with various layout and manufacturing techniques without real experiment. Simulation is one among the tools that can be accustomed to resolve issues regarding size and quality. It can forecast advanced production system behavior by analyzing the movement and interactions between elements within the systems. It helps in coming up with a layout and permits the user to assess alternatives and examine the flexibility without making large alteration or closing off any section.

1.2 Statement of the Problem

Over the years, a manufacturing company, had undergone numerous expansion programs with many new equipment of various types of manufacturing of different products were added on to the production floor due to stochastic product demand changes. The stochastic product demand here refers to fluctuation of demand for different product ranges and not of random demand changes of the specific items. Most of this equipment were installed hastily, without taking into consideration the impact of material flow which has caused tremendous strain to the smooth flow of material around the facilities. Currently, the existing approach, is placing these new production facilities in any available space in the factory without proper layout planning of the current facilities. Obvious impact, to this, would be clogged arterial flow, long delays of material replenishment and high transportation frequency causing a drop-in productivity. Hence, any planned expansion program of additional machineries to be implemented in the company needs a new approach for layout planning as to avoid production inefficiency and loss of productivity. As capacity grows, these layouts will provide many bottlenecks

(Naik and Kallurkar, 2016) and re-layout is necessary to adapt to these internal and external changes.

Due to increased competition in the manufacturing market, there is a great need for companies involved in this market to invest aggressively in expansion and development to meet the competitive and rising consumer demand.

1.3 Purpose of the Research

Manufacturing companies going through several expansion of relocation from other group overseas production sites, and production expansions may not be able to take into consideration proper facilities planning. Most of the time, it was done hastily, just to allow the production of these new products to commence production in a short time period.

This research is to develop a methodological approach in assisting manufacturing companies which has undergone expansion in its manufacturing facilities, to reconfigure or re-layout its current layout to an optimum layout.

1.4 Objectives of the Research

The objectives of this research are:

i. To study on the most common methodological approaches to (re-)configure facilities layout under stochastic product demands.

ii. To formulate a systematic approach based on Systematic Layout Process (SLP), Theory of Constraint (TOC) and develop a simulation-based approach for re-configuration of facilities layout under stochastic product demands.

iii. To validate the formulated algorithm and develop approach based on real industry case study.

iv. To evaluate the effectiveness of the developed approach, generated by the re-configuration approach.

1.5 Scope of the Research

The scopes of this research are:

i. To develop a systematic approach incorporating SLP and TOC, focused on the facilities layout with stochastic product demands.

ii. A case study of the research will be focused on the layout of a manufacturer of sewing and handicraft accessories factory.

iii. Two (2) improved layout alternatives will be developed and compared with the current planned factory layout.

iv. Material flow simulation software based on discrete event simulation technology will be used to determine which is the best option of the two alternatives, for the development of improved factory layouts.

1.6 Project Report Organization

The summary for each chapter of the report for this project are as follow:

i. Chapter 1: Introduction

This chapter entails a background of study, and it covers of introduction, problem statements, objectives of study, scope and limitation and project report organization.

ii. Chapter II: Literature Review

This chapter is based on literature reviews on related topics for this study. Mainly the literature reviews are from books, journals, articles and internet.

iii. Chapter III: Research Methodology

This chapter explains the methodologies used to carry out this study.

iv. Chapter IV: Results and Discussion

This chapter is about data collection and the preliminary analysis on several data. Various techniques and methodologies are applied in analyzing the data gathered. Analysis and discussion in this chapter are carried out in fulfilling the objectives of the research.

v. Chapter V: Conclusion and Recommendation

This chapter concludes the end results of the study of applying this systematic approach on to the case study. It will touch on several recommendation to be applied for future analysis of this approach.