MODELLING BOTTLENECK FACTORS IN A PRODUCTION LINE USING HYBRID APPROACH

WAN LAAILATUL HANIM BINTI MAT DESA

UNIVERSITI SAINS MALAYSIA

2016

MODELLING BOTTLENECK FACTORS IN A PRODUCTION LINE USING HYBRID APPROACH

by

WAN LAAILATUL HANIM BINTI MAT DESA

Thesis submitted in fulfilment of the requirement
for the degree of
Doctor of Philosophy

April 2016

ACKNOWLEDGEMENT

In The Name of Allah, The Most Gracious And The Most Merciful

First and foremost, all praises to Allah for His will, I am able to complete this research. Prayer be upon His Final Prophet and Messenger, Muhammad SAW.

I would first like to thank my supervisor, Associate Professor Dr Shahrul Kamaruddin for all the support and patience. Thank you for all the encouragements, knowledge and input you gave me throughout the duration of my PhD. To my co-supervisor, Associate Professor Dr Mohd Kamal Mohd Nawawi thanks for the encouragements, advice and suggestions given throughout the journey of my study.

A special thank you goes to Universiti Sains Malaysia, Universiti Utara Malaysia and the Malaysian Government for the funding's, sponsorship and the opportunity given to allow me to conduct this research. I really appreciate it.

Also, a special thank you is dedicated to all the staff of the Company A specially Mr. Zainuddin Md Zain and Mr Mohd Noor Abdul Majid for their full co-operation during the data collection. I convey my sincere gratitude to Allahyarham Prof Dr Razman Mat Tahar, Norazura, Ruzelan, Jafri and Linda for their assistance in model development, for helping me with the theory and application of the software which allowed me to carry out all my data analysis smoothly.

I also wish to thank all the staff of School of Quantitative Sciences (academic and technical) and my course mates at USM, who have helped me throughout these years. Also, thanks to those whom I have not mentioned their names, but they have supported, encouraged and helped me either directly or indirectly in completing my research.

Finally, I would also like to thank my family for being there for me. Your prayers, encouragements and belief in me have kept me going through those tough times. Most importantly, I would like to thank my parents (Rusnah Hamzah, Doyah Mahamod, and Mat Desa Wan Chik), my beloved husband (Mohamad Rizal Ahmad), my kids (Wan Hurin Fathanah, Wan Huda Faqihah, Baby) and my siblings for the unconditional support and unwavering patience throughout this PhD journey.

May Allah bless you all…

TABLE OF CONTENTS

CHAPTER 3 - RESEARCH METHODOLOGY

CHAPTER 4 - THE DEVELOPMENT OF THE HYBRID MODEL

CHAPTER 5 - MODEL EXPERIMENTATIONS AND DISCUSSIONS

CHAPTER 6 - CONCLUSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AB	Agent-Based Modelling
ABS	Agent-Based Simulation
AI	Artificial Intelligence
ANOVA	Analysis of Variance
CLD	Causal Loop Diagram
CT	Cycle Time
DCT	Dimensional Consistency Test
DES	Discrete Event Simulation
ECT	Extreme Condition Test
FLE	Fixed Leading Edge
FMS	Flexible Manufacturing System
FTE	Fixed Trailing Edge
GA	Genetic Algorithms
GSBP	General Shifting Bottleneck Procedure
HSBBM	Hybrid Simulation-Based Bottleneck Management
IE	Industrial Engineering
MCS	Monte Carlo Simulation
MILP	Mix Integer Linear Programming
NDT	Non-Destructive Test
NVA	Non-Value Added

OBBSIP	Outcome-And-Behaviour-Based Safety Incentive Program
OEE	Overall Equipment Effectiveness
OR	Operational Research
PSDA	Production Scheduling Decomposition Algorithm
SA	Simulated-Annealing
SD	System Dynamics
SFD	Stock-Flow Diagram
SIP	Safety Incentive Program
SPSB	Safety Precautions and Safe Behaviours
TOC	Theory of Constraints
TP	Throughput
TWT	Total Weighted Tardiness
VA	Value Added
WACC	Worker Accident Compensation Claim/s
WIP	Work in Process

LIST OF SYMBOLS

R	Correlation Coeffficient
RMSPE	Root Mean Square Percentage Error
SDA	Standard Deviation of Actual Data
SDS	Standard Deviation od Simulated Data
X_s	Simulated Data
X_a	Actual Data
UT	Inequity Coeffecient
$\overline{N}$	Average Number of Jobs in the System
$\overline{W}$	Average Time a Job Spends in The System (Mean Flow Time)
λ	Average Arrival Rates to the System
H_0	Hypothesis Null
H_1	Hypothesis Alternative
df	Degree of Freedom
MS	Mean of Squares
SS	Sum of Squares

PEMODELAN FAKTOR-FAKTOR KESESAKAN DALAM TERTIB PENGELUARAN MENGGUNAKAN PENDEKATAN HIBRID

ABSTRAK

Kesesakan boleh berlaku bagi kebanyakan organisasi perniagaan, sama ada perkhidmatan atau operasi pembuatan. Dalam sektor pembuatan, kesesakan biasanya berlaku disebabkan oleh kegagalan yang berulang-ulang dalam aliran sistem pengeluaran. Selain itu, terdapat beberapa faktor yang boleh menyebabkan kesesakan dalam tertib pengeluaran, seperti masa menunggu yang lama, tunggakan yang besar dan tahap tekanan yang tinggi. Faktor kesesakan ini boleh mengurangkan kadar pengeluaran dalam tertib pengeluaran dan memberi kesan negatif terhadap kos pengeluaran. Oleh itu, ia perlu ditangani untuk meningkatkan prestasi sistem pengeluaran dan melancarkan aliran produk. Lantaran itu, terdapat keperluan bagi pengilang untuk mencari jalan dalam menguruskan faktor-faktor kesesakan. Umumnya, kesesakan boleh berpunca dari faktor ketara dan faktor tidak ketara. Walau bagaimanapun, faktor tidak ketara kurang mendapat perhatian dari penyelidik terdahulu. Kebanyakkan kajian sebelum ini memberikan tumpuan kepada faktor yang ketara seperti bilangan pemprosesan tetapi kurang memberi tumpuan terhadap faktor tidak ketara seperti tahap tekanan pekerja. Oleh itu, kajian ini mengkaji faktor tidak ketara yang menekankan kepada faktor manusia terutamanya dalam memahami kesan ketidakhadiran dalam tertib pengeluaran. Di samping itu, kajian ini juga mengenal pasti punca kesesakan bagi menggambarkan hubungan antara faktor manusia dan tertib pengeluaran. Ketidakhadiran merujuk kepada keadaan apabila tenaga kerja yang ada adalah kurang daripada jumlah tenaga kerja yang diperlukan dalam barisan pengeluaran. Faktor manusia memainkan peranan penting dalam menentukan kadar pengeluaran. Dalam tesis ini, model simulasi hibrid digunakan untuk menganalisis masalah ketidakhadiran dalam pembuatan komposit pesawat dengan mengintegrasikan model simulasi peristiwa diskret (DES) dan Sistem Dinamik (SD) yang dinamakan sebagai *Hybrid Simulation Based Bottleneck Management* (HSBBM). Untuk menganalisis kesan ketidakhadiran, jumlah pemprosesan, masa menunggu, kerja dalam proses (WIP) dan masa kitaran dianalisis dalam pelbagai senario perancangan pengeluaran. Hasil menunjukkan bilangan pekerja yang tidak hadir di tertib pengeluaran meningkatkan beban kerja kepada pekerja yang ada dan memberi kesan terhadap kadar pengeluaran. Dengan mempertimbangkan ketidakhadiran, bilangan pemprosesan berkurangan sebanyak 12.67% berbanding dengan rancangan pengeluaran yang menunjukkan bahawa, model hibrid mampu untuk mewakili keadaan yang lebih realistik apabila melibatkan faktor manusia. Kesimpulannya, model hibrid yang dibangunkan boleh digunakan untuk menggambarkan dan mengukur kesan tingkah laku manusia yang membawa kepada kesesakan dan dapat membantu pihak pengurusan untuk menjana perancangan pengeluaran yang lebih relevan.

MODELLING BOTTLENECK FACTORS IN PRODUCTION LINE USING HYBRID APPROACH

ABSTRACT

A bottleneck can occur in almost all business organizations, either services or manufacturing operations. In manufacturing sector, bottleneck normally occurs due to repetitive failures in the flow of production system. Besides that, there are several factors that can cause bottleneck events in the production line, such as long waiting time, huge backlog and high stress level. These bottleneck factors can reduce the throughput rate in the production line and negatively affect the production costs. Therefore, it should be tackled for a high production system performance and a smooth flow of products. Because of that, there is a need for the manufacturers to find ways in managing the bottleneck factors. In general, bottlenecks can be caused by tangible and intangible factors. However, the intangible factors have received less attention by the previous researchers. Most previous works had focused on tangible factor such as number of throughput but lack in intangible such as on workers stress level. Thus, this research investigates the intangible factors which emphasizes on human factor particularly in understanding the effect of absenteeism in the production line. In addition, this study also identifies causes of bottleneck in illustrating the relationship between human factors and production line. Absenteeism refers to a situation when the available manpower is less than the number of manpower needed on the production line. This human factor plays an important role in determining the production rate. In this thesis, a hybrid simulation model is used to analyse the absenteeism problem in an aircraft composite manufacturing by integrating a Discrete Event Simulation (DES) and a System Dynamics (SD) models which namely as *Hybrid Simulation Based Bottleneck Management* (HSBBM). To analyse the effect of absenteeism, the amount of throughput, waiting time, work in process (WIP) and cycle time are analysed in various scenarios of production planning. The result shows the number of absentees at production line increase the workload to the available worker and gives effect to the production rate. By considering the absenteeism, the number of throughput decrease 12.67% compared to the production plan indicating that the hybrid model is able to represent more realistic situation when involving human factor. In conclusion, the developed hybrid model can be used to visualise and quantify the impacts of human behaviour that lead to bottlenecks and able to assist the management to generate more relevant production plan.

CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter briefly discusses the idea of research on bottleneck in production line. It also covers the underlying background, principles as well as the problem statement, research questions, research objectives, scopes of this research and the structure of this thesis. The final part discusses the summary of this chapter.

1.1 Research Background

Bottleneck refers to a constraint within a system that limits the throughput (Jacobs and Chase, 2014). Bottleneck can occur in almost all business organisations, either services or manufacturing operations. In manufacturing, for example, bottleneck can contribute to negative impact on the production line. In general, bottlenecks can be caused by tangible (i.e., number of throughput and number work in process, WIP) and intangible (i.e., stress level and motivation) factors. Thus, bottleneck can trigger instability to the amount of throughput in a production system. There are several factors that can cause bottleneck scenario, such as repetitive failures in the flow of production system, waiting time, backlog and the stress level in the production line. Timilsina

(2012) listed several factors that can cause bottleneck in manufacturing, which include manpower, process, management, policy and also environmental.

Bottleneck can reduce the throughput rate in the production line and negatively affect the production costs. According to Chiang et al. (2001), there is 30%-40% reduction in the system efficiency due to bottleneck in the production line. Some of the approaches to increase the throughput rate when bottleneck problem occur in the production line has been addressed (Li et al., 2011). However, the analysis on bottleneck has been overlooked by those who have influence or deal with the production process since there are no standard tools to properly measure the bottleneck (Salahshoor et al., 2011). According to Glazner (2009), the production managers who act as decision makers identify the need to have appropriate tools and techniques that can assist them to understand the effects of bottleneck on the production behaviour and to manage the complexity of the production flow.

From the previous paragraph, there are enough evidences to show that many manufacturers and scholars are concerned about bottleneck problem in the production line. To reduce the complexity of production management and to keep the efficiency of the production system, it is important that the bottleneck scenario in the production system be given serious attention, especially to the causes of bottleneck scenario and the way to minimise the disruption caused by this scenario (Lu et al., 2006). Managing the bottlenecks effectively and efficiently could yield higher system throughput (Elfman, 1999). However, designing and implementing a proper bottleneck mitigation strategy in