Faculty of Manufacturing Engineering

INTEGRATION FRAMEWORK OF SIMULATION-BASED DATA ANALYTICS AND INTERNET OF THINGS FOR LEAN MANUFACTURING DECISION-MAKING

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MOHD SOUFHWEE BIN ABD RAHMAN

A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Integration Framework of Simulation-Based Data Analytics And Internet of Things For Lean Manufacturing Decision-Making” 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.

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Name : Mohd Soufhwee bin Abd Rahman

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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DEDICATION

Most notably, a highest gratitude and grateful to Allah s.w.t. for His mercy and love. This study is wholeheartedly dedicated to my beloved wife, Aieen Hafasa@Helda binti Amin and my dearly son, Lubbna Humairaa Wijaya, Arwiss Qarnee Wijaya, Raihanni Humairaa Wijaya, and Anaqhalish Humairaa Wijaya who have been my source of motivation and gave me strength during the journey, and continually provide their unconditional loves and patience for me. I also dedicate this work to my family members, in-laws all my friends for their prayers and supportive expression towards my interest of study.

ABSTRACT

Lean Manufacturing (LM) is a deep-rooted mechanism which has been extensively utilised in diverse business sectors globally so as to constantly enhance operations. Evolving technologies have taken manufacturing systems to a new level because of the blend of digital and physical systems in the Industry 4.0 progression. A literature review indicates that the significance of Industry 4.0 in LM has been extremely underlined in recent times. Notably, the swift development of main Industry 4.0 technologies has triggered enormous data in the production sector. This is because production activities are deploying Industry 4.0 technologies for catering to demands of consumers for all-round products. Besides this expansion, there are rising apprehensions about making intricate decisions appropriately. Data is not being utilised diligently by means of digital systems, and hence the resulting variables utilised in the simulation model are imprecise. The Internet of Things (IoT) is seen as a technology to back LM; however, there is not enough deployment of this technology. IoT is not being utilised widely to gather, store, and link data into the simulation as a rooted system in the decision-making procedure. According to a semi-structured interview of 15 firms, 87.7% intensely concur that IoT should be enabled as a platform to bolster LM decision-making. As decision-making is supplemented by a huge volume of data and simulation to carry out the analysis, it is tough to build a framework which integrates simulation, data, and IoT technology. Hence, the study intends to recommend a conceptual structure called iLMDM, which assimilates LM and simulation-based data analytics by way of IoT to enable decision-making in process enhancements. This study is carried out by deploying the systematic literature review approach by means of a mixed-methods technique. Thus, the iLMDM structure is an extremely effectual way of backing management decision procedures about process enhancement and custom-made Industry 4.0 execution. This study's key contributions are related to the 4WRD policy objectives to bolster the shift to Industry 4.0. With regards to the economy, the policy targeted RM392 billion to propel the national economy, whereas productivity rose by 30% and skill workers rose by 35%. Hence, the outcomes of the iLMDM-based study are focused on productivity, economic, and worker utilisation. The management can now ascertain other resource configurations which have to be examined and optimised on the basis of the performance which has been brought into line.

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KERANGKA BERSEPADU ANALISIS DATA BERASASKAN SIMULASI DAN INTERNET PELBAGAI BENDA UNTUK MEMBUAT-KEPUTUSAN PEMBUATAN KEJAT

ABSTRAK

Pembuatan Kejat (LM) ialah sebuah mekanisma berakar umbi yang telah digunakan secara meluas dalam pelbagai sektor perniagaan di seluruh dunia untuk meningkatkan operasi secara berterusan. Teknologi yang berkembang telah membawa sistem pembuatan ke tahap baharu kerana gabungan sistem digital dan fizikal dalam perkembangan Industri 4.0. Kajian literatur menunjukkan bahawa kepentingan Industri 4.0 di dalam LM sangat ditekankan kebelakangan ini. Terutamanya, pembangunan pantas teknologi utama Industri 4.0 telah mencetuskan data yang besar dalam sektor pengeluaran. Ini disebabkan perkembangan aktiviti dalam bidang pembuatan menggunakan teknologi Industri 4.0 bagi memenuhi permintaan pelanggan terhadap produk yang serba lenkap. Seiring dengan pengembangan ini, terdapat kebimbangan yang semakin meningkat terhadap proses membuat keputusan yang rumit dengan betul. Data tidak dimanfaat secara intensif melalui sistem digital mengakibatkan pemilihan pembolehubah dalam model simulasi adalah tidak tepat. Internet pelbagai benda (IoT) dilihat sebagai teknologi untuk menyokong LM, namun penggunaan teknologi ini tidak mencukupi. IoT tidak digunakan secara meluas untuk mengumpul, menyimpan dan menyambung data ke dalam simulasi sebagai sistem terbenam dalam prosedur membuat keputusan. Menurut temu bual separa berstruktur terhadap 15 firma, 87.7% sangat bersetuju bahawa IoT harus didayakan sebagai platform untuk memperkukuh pembuatan keputusan LM.Memandangkan proses analisa membuat keputusan melibatkan sejumlah data yang besar menggunakan simulasi, terdapat ruang untuk membina rangka kerja yang menggabungkan data, simulasi dan IoT dengan mengekalkan pemikiran LM. Oleh itu, kajian ini berhasrat untuk mengesyorkan struktur konsep yang dipanggil iLMDM, yang mengasimilasikan LM dan analisis data berasaskan simulasi melalui IoT untuk membolehkan pembuatan keputusan dalam peningkatan proses. Penyelidikan ini dijalankan dengan menggunakan kaedah tinjauan literatur sistematik melalui pendekatan kaedah campuran. Oleh itu, struktur iLMDM ialah cara yang sangat berkesan untuk menyokong prosedur keputusan pengurusan tentang peningkatan proses dan pelaksanaan Industri 4.0 yang dibuat khas. Sumbangan utama penyelidikan ini sejajar dengan matlamat dasar 4WRD untuk menyokong peralihan kepada Industri 4.0. Dari segi ekonomi, dasar itu menyasarkan RM392 bilion untuk meningkatkan ekonomi negara, manakala peningkatan produktiviti adalah sebanyak 30% dan kemahiran pekerja meningkat sebanyak 35%. Dengan itu, hasil kajian berdasarkan iLMDM adalah tertumpu kepada faktor ekonomi, produktiviti dan penggunaan pekerja, dan pihak pengurusan kini boleh mengenal pasti konfigurasi sumber alternatif yang perlu disiasat dan dioptimumkan berdasarkan prestasi yang telah diselaraskan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AB	-	Agent-Based
ABDI	-	Agência Brasileira de Desenvolvimento Industrial
AI	-	Artificial Intelligent
AR	-	Augment Reality
AM	-	Agile Manufacturing
CAD	-	Computer-Aided Design
CAM	-	Computer-Aided Manufacturing
CDA	-	Confidential Disclosure Agreement
CE	-	Concurrent Engineering
CIM	-	Computer Integrated Manufacturing
CPS	-	Cyber-Physical Systems
CTI	-	Cost-Time Investment
CTP	-	Cost-Time Profiles
DA	-	Data Analytics
DEA	-	Data Envelopment Analysis
DES	-	Discrete Event Simulation
DOE	-	Design of Experiments
DSS	-	Decision Support System
FMEA	-	Failure Mode and Effects Analysis
GDP	-	Gross Domestic Product
GII	-	Global Innovation Index
ICS	-	Industrial Control Systems
ICT	-	Information Communication Technology
IDC	-	International Data Corporation
iLMDM	-	Integrated LM Decision-Making

IMVP	-	International Motor Vehicle Program
IoP	-	Internet of People
IoS	-	Internet of Service
IoT	-	Internet of Things
IT	-	Information Technology
IVI	-	Industrial Value Chain Initiative
JIT	-	Just in Time
KPI	-	Key Performance Indicators
LM	-	Lean Manufacturing
L-OST	-	Lean-Oriented Optimum-State Control Theory
LPD	-	Lean Product Development
MCO	-	Movement Control Order
MES	-	Manufacturing Execution Systems
MITI	-	Ministry of International Trade and Industry
MNCs	-	Multinational Corporations
NVA	-	Non Value-Added
OM	-	Operation Management
OR	-	Operation Research
OT	-	Operational Technology
PDCA	-	Plan, Do, Check, Action
PLC	-	Programmable Logic Controllers
Q	-	Question
QC	-	Quality Control
QFD	-	Quality Function Deployment
QRM	-	Quick Response Manufacturing
RFID	-	Radio Frequency Identification
RO	-	Research Objective

RQ	-	Research Questions
SD	-	System Dynamics
SLR	-	Systematic Literature Review
SQL	-	Structured Query Language
SMED	-	Single-Minute Exchange of Die
SMO	-	Multi-Objective Optimization
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
TDABC	-	Time-Driven Activity-Based Costing
TPC	-	Throughput Costing
TPM	-	Total Productive Maintenance
TPS	-	Toyota Production System
UTeM	-	Universiti Teknikal Malaysia Melaka
VA	-	Value Added
VFF	-	Virtual Factory Framework
VSM	-	Value Stream Mapping
WEF	-	World Economy Forum
4WRD	-	National Policy on Industry 4.0
5S	-	Sort, Set in order, Shine, Standardize and Sustain.

LIST OF APPENDICES