DEVELOPMENT OF AN INTEGRATED ERGONOMICS PRINCIPLES FRAMEWORK WITH MANUFACTURING PROCESS FLOW IN MALAYSIAN INDUSTRY

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2022

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

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Development of an Integrated Ergonomics Principles Framework with Manufacturing Process Flow in Malaysian Industry" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : FATIN AYUNI BINTI MOHD AZLI LEE

Date : 25th MARCH 2022

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 Master of Science in Manufacturing Engineering.

Signature : ....

Supervisor Name : DR. RADIN ZAID BIN RADIN UMAR

Date : 25th MARCH 2022

DEDICATION

Special dedication to my beloved parents and siblings.

Their encouragement and guidance have always been an inspiration to me along with this education journey.

ABSTRACT

Manufacturing engineers generally schedule their activities along manufacturing process flow. Nevertheless, there are limited documentations that integrate ergonomics principles into the manufacturing process flow format. This study aims to address the issue by developing an ergonomics framework that integrates ergonomics principles with manufacturing process flow. This research was divided into three phases. In Phase 1, ergonomics implementation challenges among practitioners in Malaysian manufacturing industry was identified through thematic analysis of literature reviews and interviews. In Phase 2, a proposed framework mapping general ergonomic improvements to the general manufacturing process flow were generated through in-depth discussion and generative sessions. Phase 3 is a validation process, where the study outcomes were reviewed and validated by professional practitioners through a mixed method of descriptive analysis and Fuzzy Delphi Method (FDM). Phase 1 findings showed that limitations of 'ergonomics documentation' and 'ergonomics knowledge' are identified as primary challenges faced by engineers in implementing ergonomics. Results from Phase 2 revealed six general manufacturing process flows themes that are applicable in different Malaysia's manufacturing sectors: 'Incoming raw materials', 'inspection of raw materials', 'assembly/production/fabrication', 'quality inspection', 'packaging', and 'shipment of end-product'. These six process flows were mapped to sixteen ergonomic engineering improvement components, which related to provision of tools, equipment, devices, or mechanisms to 1) 'improve working height level'; 2) 'reduce forceful exertion'; 3) 'reduce contact stress'; 4) 'assist manual work and manual material handling activities'; 5)' reduce excessive reach'; 6) 'improve grips'; 7) 'maintain neutral postures of neck'; 8) 'minimize the frequency of work movements'; 9) 'maintain neutral postures of upper limbs'; 10) 'minimize fatigue'; 11) 'reduce vibration'; 12) 'improve space and clearance'; 13) 'improve visibility'; 14) 'improve layout and arrangement'; 15) 'allow good body balance and stability'; and 16) 'improve the environment'. Validation in Phase 3 with all expert participants shows general agreement rating obtained on the ergonomics implementation challenges, and the newly proposed framework's components. The FDM findings show that assembly/production/fabrication process acquires all the general ergonomic engineering improvements. Eight general ergonomic engineering improvements have been determined to be applicable in all processes within the manufacturing process flows. In conclusion, the developed framework may provide an overview or roadmap of how and where manufacturing engineers and managers can actively support the implementation of ergonomics initiatives in a manufacturing process flow format.

PEMBANGUNAN RANGKA KERJA PRINSIP ERGONOMIK BERSEPADU DENGAN ALIRAN PROSES PEMBUATAN DALAM INDUSTRI DI MALAYSIA

ABSTRAK

Jurutera pembuatan secara umumnya menjadualkan aktiviti mereka berdasarkan aliran proses pembuatan. Namun begitu, terdapat rangka kerja dan dokumentasi yang terhad mengintegrasikan prinsip ergonomik dalam format aliran proses pembuatan. Kajian ini bertujuan untuk untuk menangani isu tersebut dengan membangunkan rangka kerja ergonomik yang mengintegrasikan prinsip ergonomik dengan aliran proses pembuatan. Penyelidikan ini dibahagikan kepada tiga fasa. Dalam Fasa 1, cabaran pelaksanaan ergonomik dalam kalangan pengamal dalam industri pembuatan Malaysia telah dikenal pasti melalui analisis tematik dari tinjauan literatur dan temu bual. Dalam Fasa 2, rangka kerja dibangunkan dengan memetakan peningkatan umum ergonomik ke dalam aliran umum proses pembuatan melalui perbincangan mendalam dan sesi generative. Fasa 3 ialah proses pengesahan, di mana hasil kajian disemak dan disahkan oleh pengamal profesional menggunakan campuran kaedah analisis deskriptif dan Kaedah Fuzzy Delphi (KFD). Penemuan Fasa 1 menunjukkan bahawa 'dokumentasi ergonomik' dan 'pengetahuan ergonomik' dikenal pasti sebagai cabaran utama yang dihadapi oleh jurutera untuk melaksanakan ergonomik. Keputusan dari Fasa 2 mendedahkan enam aliran umum proses pembuatan yang terdapat dalam pelbagai sektor pembuatan di Malaysia: 'Bahan mentah masuk', 'pemeriksaan bahan mentah', 'pemasangan/pengeluaran/fabrikasi', 'pemeriksaan kualiti', 'pembungkusan', dan 'penghantaran produk akhir'. Enam aliran proses ini telah dipetakan kepada enam belas komponen penambahbaikan umum kejuruteraan ergonomic, yag berkaitan dengan penyediaan alat, peralatan, peranti, atau mekanisme untuk 1) 'meningkatkan tahap ketinggian kerja'; 2) 'mengurangkan tenaga yang kuat'; 3) 'mengurangkan hubungan tekanan'; 4) 'membantu kerja manual dan aktiviti pengendalian bahan manual'; 5) 'mengurangkan jangkauan berlebihan'; 6) 'meningkatkan cengkaman'; 7) 'mengekalkan postur leher yang neutral'; 8) 'meminimumkan kekerapan pergerakan kerja'; 9) 'mengekalkan postur anggota badan atas yang neutral'; 10) 'mengurangkan keletihan'; 11) 'mengurangkan getaran'; 12) 'meningkatkan ruang dan pelepasan'; 13) 'meningkatkan penglihatan'; 14) 'memperbaiki susun atur dan susunan'; 15) 'membenarkan keseimbangan dan kestabilan badan yang baik'; dan 16) 'memperbaiki persekitaran'. Pengesahan dalam Fasa 3 dengan semua pakar menunjukkan persetujuan diperoleh mengenai cabaran pelaksanaan ergonomik dan komponen rangka kerja yang dibangunkan. Penemuan FDM menunjukkan bahawa proses pemasangan/pengeluaran/fabrikasi memperoleh semua peningkatan umum kejuruteraan ergonomik. Lapan peningkatan kejuruteraan ergonomik umum telah dikenal pasti terpakai untuk semua proses pembuatan. Kesimpulannya, rangka kerja yang dibangunkan dapat memberikan gambaran umum atau peta jalan bagaimana dan di mana jurutera dan pengurus pembuatan dapat menyokong secara aktif pelaksanaan inisiatif ergonomik dalam format aliran proses pembuatan.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heartfelt gratitude to Allah SWT for providing me with the opportunity to continue my study, wisdom and knowledge, good health, sufficient time, and all types of assistance and resources till this study is completed.

I want to express millions of gratitude to my supervisor, Dr Radin Zaid bin Radin Umar, who has helped me with valuable critical insights and guidance, constructive comments, and attentive reading in refining and strengthening my study. Thank you also for your unwavering commitment and patience with my flaws. My sincere gratitude is also given to my co-supervisor, Dr Isa bin Halim, for his help and support.

To my parents, Mohd Azli Lee bin Abdullah and Abdah binti Idris, thank you for your continued prayers and encouragement. May Allah SWT grant the highest level of Jannah to you. Thank you also to my siblings. I may not be able to complete my research without their motivation and encouragement.

Lastly, I would like to thank my colleagues, and everyone associated with this study for their support and assistance in providing feedback and advice. May Allah SWT bless you.

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LIST OF ABBREVIATIONS

CPE	–	Certified Professional Ergonomist
DOSH	–	Department of Occupational Safety and Health
DOSM	–	Department of Statistic Malaysia
ERF	–	Ergonomics Risk Factors
FDM	–	Fuzzy Delphi Method
FMEA	–	Failure Mode and Effects Analysis
GDP	–	Gross Domestic Product
HEDOMS	–	Human Error and Disturbance Occurrence in Manufacturing Systems
HF	–	Human Factors
HEI	–	Human Error Identification
HIRARC	–	Hazard Identification, Risk Assessment and Risk Control
IPI	–	Industrial Production Index
MAS	–	Motion Analysis System
MMH	–	Manual Material Handling
MSDs	–	Musculoskeletal Disorders
NIOSH	–	National Institute for Occupational Safety and Health
OHS	–	Occupational Safety and Health
OPL	–	One Point Lesson
PCA	-	Printed Circuit Assembly

PDCA	–	Plan, Do, Check, and Act
PE	–	Participatory Ergonomics
QC	–	Quality Control
SMEG	–	Surface Electromyography
SMI	–	Small and Medium Industries
SHO	–	Safety and Health Officer
SOP	–	Standard Operating Procedures
SSQI	–	Six Sigma Quality Index
TFN	–	Triangular Fuzzy Numbers
VSM	–	Value Stream Mapping
WRMSDs	–	Work-related Musculoskeletal Disorders

LIST OF SYMBOLS

Amax	–	Defuzzification
d	–	Threshold value
m1	–	Average of minimum value
m2	–	Average of the most plausible value
m3	–	Average of maximum value
n1	–	Minimum value
n2	–	Most plausible value
n3	–	Maximum value
α-cut	–	Fuzzy number

LIST OF PUBLICATIONS

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[1] Umar, R. Z. R., Lee, F. A. M. A., Khafiz, M. N., Ahmad, N., & Abdullasim, N. (2020). Space Mapping of Hip and Wrists Motions for Different Transfer Distances in Manual Material Handling Task. *IIUM Engineering Journal*, 21(2), 164-176.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

In Malaysia, the manufacturing sector contributes to the country's Gross Domestic Product (GDP). According to the statistics released by the Department of Statistic Malaysia (DOSM), the manufacturing sectors are one of the main drivers, and it is the second-largest contributor to the Malaysian economy after the services sectors. Over the last five years, the manufacturing industry has contributed around 22% of the total economic sectors to GDP (Department of Statistics Malaysia, 2021). Data from DOSM also indicates that the manufacturing sector contributes to the constant trend of the employment rate in Malaysia. The data from 2010 to 2020 show that the number of employments in the manufacturing industry is around 17% to 18% of Malaysia's total employed persons (Department of Statistics Malaysia, 2021).

Employment in manufacturing consists of white-collar and blue-collar workers. Cooper and Williams (1991) reported that blue-collar workers are more exposed to work-related health risks than white-collar and professional workers. Blue-collar workers or low-skilled labour mostly work as technicians and operators with some degree of manual task assignments, especially as there are still limited operations of the fully automated and smart manufacturing system in Malaysia. For now, the industrial revolution of Malaysia's manufacturing sectors is between Industry 2.0 and 3.0 (Ling et al., 2020). The involvement of these blue-collar workers or low-skilled labour in manufacturing sectors indicates a high degree of interactions between human (workers) and other work system components in manufacturing, such as equipment, tasks, and workplace environments. According to Liang and Xiang (2004), ergonomic problems are one of the blue-collar workers' main problems. Thereby, ergonomics has emerged as a specialized discipline that optimizes the relationships between workers and their work systems.

Several studies have stated that the majority of companies and workers in Malaysia's manufacturing industry already have ergonomic awareness (Mustafa et al., 2009; Deros et al., 2010; Noor et al., 2020). The study by Mustafa et al. (2009) on the level of ergonomics awareness in Malaysian manufacturing industry showed that 35.6% of respondents consisted of managers, human resources, officers, engineers, and safety and health professionals had a high level of ergonomic awareness while 51.1% of them had a moderate level of ergonomics awareness. Similar trends were discovered by Deros et al. (2010) in their study of ergonomics awareness among workers performing manual material handling activities. The authors reported that only 18.8% of workers realize the negative consequences of neglecting ergonomics at their workplace. Despite a relatively acceptable level of ergonomics awareness, it was found that there are still prevailing issues with implementation processes.

Few issues with ergonomic implementation are related to limited ergonomic knowledge, lack of ergonomic education, lack of ergonomic training, lack of time, and lack of finances (Mustafa et al., 2009; Sirat. et al., 2018). An article reviewed by Yusuff et al. (2016) summarized several problems related to ergonomics standards, particularly on its development, awareness, and implementation. Generally, the authors mentioned that the technical committees consisting of representatives from government agencies, employer federations, trade and industry associations, occupational safety and health associations, academicians, and non-governmental organizations are not aware of existing ergonomics standards, do not know how to implement ergonomics programs and have difficulties to