UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF INSTRUMENT PLACEMENT CRITERIA AND CLASSIFICATION METHOD FRAMEWORK FOR PROCESS INDUSTRY IN MALAYSIA

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

I declare that this thesis entitled "Development of Instrument Placement Criteria and Classification Method Framework for Process Industry in Malaysia" 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 : ....

Date : ....

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 : ....

Date : ....

DEDICATION

In the name of Allah, the most Gracious, the most Merciful.

Special dedication to my beloved wife, twin babies, parents, and siblings who has been my constant source of support and encouragement throughout my postgraduate journey.

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ABSTRACT

Instruments are devices that convey real-time information on equipment and piping operation status, such as temperature, flow rate, pressure, and many more Instruments are used heavily across various processing facilities for continuous monitoring, inspection, control, and maintenance to ensure safe and profitable plant operation. As such, physical interaction between human operators and instruments are inevitable. However, there are limited documentations from both academic and industrial standpoints that focus on instrument placement designs with appropriate Human Factors Engineering (HFE) integration to facilitate safe and efficient task activities performed by operators. Hence, this study aims to address the gap by developing Instrument Placement Criteria and Classification Method (IPCCM) framework to assist design engineers in classifying, planning, and designing instrument placements based on their critical function in the process facility to facilitate safe and efficient task activities. This study was conducted in three phases. In Phase 1, the best HFE practices in instrument placement design and challenges to implement them were identified through thematic analysis of literature review, document review, and interview. In Phase 2, a preliminary IPCCM framework was developed through thematic analysis of document review, interview, and verified through Focus Group Discussion (FGD). In Phase 3, the verified IPCCM framework was reviewed and validated by industrial experts using Fuzzy Delphi Method (FDM) analysis. Overall, findings from Phase 1 indicate that there are several challenges faced by industrial practitioners to implement best HFE practices in instrument placement designs which permits for potential rooms of improvements during facility design process. Results from Phase 2 reveal 6 criteria that influence instrument placement design in process facility: (1) function in process control, (2) frequency of access during operation, (3) frequency of access during maintenance (4) function in safeguarding, (5) type of activity during access, and (6) type of activity during maintenance. These criteria consist of multiple sub-criteria that can be classified into 3 instrument criticality levels: Category 1 (Very critical), Category 2 (Critical), and Category 3 (Not critical). Following this framework, instruments can be designed and placed according to their criticality level. Validation conducted in Phase 3 shows promising agreement rating on the proposed IPCCM framework in terms of (1) criteria that influence instrument placement, (2) instrument classification method, and (3) the resulting placement design requirement. In conclusion, the validated IPCCM framework is expected to assist in closing the identified gaps and aid design engineers in improving instrument placement design process and quality for process facility development in Malaysia.

PEMBANGUNAN KRITERIA PENEMPATAN ALATAN DAN RANGKA KERJA KAEDAH PENGELASAN UNTUK INDUSTRI PROSES DI MALAYSIA

ABSTRAK

Peranti maklumat adalah satu alat yang digunakan untuk memaparkan maklumat berkaitan status sesuatu peralatan atau sistem perpaipan seperti suhu, kadar aliran, tekanan, dan sebagainya. Peranti ini digunakan secara meluas dalam fasiliti berasaskan proses untuk tujuan pemantauan, pemeriksaan, operasi, dan penyelenggaraan secara berterusan. Justeru, interaksi fizikal antara pekerja dengan peranti maklumat adalah sangat penting untuk memastikan operasi fasiliti yang selamat dan efisyen. Namun, dokumentasi dan penerbitan sedia ada sama ada dari bahagian akademik mahupun industri yang khusus dalam reka bentuk peletakan peranti maklumat berdasarkan komponen Kejuruteraan Faktor Manusia (KFM) adalah terhad. Justeru, kajian ini dijalankan untuk merapatkan jurang tersebut melalui pembangunan rangka kerja Kaedah Pengkelasan dan Peletakan Peranti Maklumat (KPPM) bagi memudahkan para jurutera untuk mengelas, merancang, dan mereka bentuk peletakan peranti maklumat berdasarkan fungsi kritikalnya dalam sesebuah fasiliti berasaskan proses. Ringkasnya, kajian ini dijalankan secara berperingkat melalui tiga fasa. Dalam Fasa 1, amalan KFM terbaik berkaitan reka bentuk peletakan peranti maklumat dan cabaran untuk melaksanakannya telah dikenal pasti melalui analisa tematik dari tinjauan litetatur, dokumen, dan temu bual. Dalam Fasa 2, rangka kerja rintis KPPM telah dibangunkan melalui analisa tematik dari tinjauan dokumen, temu bual, dan disahkan melalui Perbincangan Kumpulan Bersasar (PKB). Dalam Fasa 3, rangka kerja rintis tersebut telah dinilai dan ditentusahkan oleh pakar industri menggunakan Kaedah Fuzzy Delphi (KFD). Secara keseluruhan, penemuan dalam Fasa 1 menunjukkan bahawa terdapat beberapa cabaran yang dihadapi oleh pengamal industri untuk melaksanakan amalan KFM terbaik dalam proses reka bentuk peletakan peranti maklumat. Melalui fasa ini juga, beberapa ruang penambahbaikan telah dikenalpasti. Dalam Fasa 2, 6 kriteria yang mempengaruhi reka bentuk peletakan peranti maklumat dalam fasiliti berasaskan proses telah dikenalpasti, iaitu (1) fungsi dalam kawalan proses, (2) kekerapan akses ketika operasi, (3) kekerapan akses ketika penyelenggaraan, (4) fungsi dalam keselamatan fasiliti, (5) jenis aktiviti ketika akses, dan (6) jenis aktiviti ketika penyelenggaraan. Setiap kriteria mempunyai beberapa pecahan sub-kriteria yang boleh dikelaskan kepada 3 peringkat kritikal: Kategori 1 (sangat kritikal), Kategori 2 (kritikal), dan Kategori 3 (tidak kritikal). Setiap peranti maklumat yang telah dikelaskan perlu direka dan diletakkan berdasarkan peringkat kritikalnya. Seterusnya, proses penentusah yang dijalankan dalam Fasa 3 menunjukkan nilai persetujuan yang memberangsangkan berkaitan (1) kriteria, (2) kaedah pengkelasan, dan (3) keperluan reka bentuk peletakan peranti maklumat. Sebagai rumusan, rangka kerja KPPM yang telah dibangun dan ditentusahkan ini dijangka untuk merapatkan jurang dan membantu para jurutera untuk meningkatkan kualiti dan menambah baik proses reka bentuk peletakan peranti maklumat dalam pembinaan fasiliti berasaskan proses di Malaysia.

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LIST OF ABBREVIATIONS

3D	–	3 Dimensional
ABS	–	American Bureau of Shipping
ASTM	–	American Society for Testing and Materials
BFD	–	Block Flow Diagram
BOQ	–	Bill of Quantity
BP	–	British Petroleum
BPAPC	–	British Petroleum-American Production Company
CAD	–	Computer-aided Design
CAPEX	–	Capital Expenditure
CPP	–	Central Processing Platform
DD	–	Detailed Design
DM	–	Delphi Method
DOSH	–	Department of Occupational Safety and Health
EWSB	–	ErgoWorks Sdn. Bhd.
FDM	–	Fuzzy Delphi Method
FDP	–	Field Development Plan
FEED	–	Front-end Engineering Design
FGD	–	Focus Group Discussion
FMA	–	Factory and Machinery Act
FSO	–	Floating Storage and Offloading Unit

GT	–	Grounded Theory
HESS	–	HESS Exploration & Production Malaysia B.V
HF	–	Human Factors
HFE	–	Human Factors Engineering
HSE	–	Health, Safety, and Environment
HUC	–	Hook-up and Commissioning
IADC	–	International Association of Drilling Contractors
IEA	–	International Ergonomics Association
IOGP	–	International Association of Oil and Gas Producers
IPCCM	–	Instrument Placement Criteria and Classification Method
ISA	–	Instrumentation, System, and Automation Society
MAH	–	Major Accident Hazard
MMHE	–	Malaysia Marine and Heavy Engineering Sdn. Bhd
MoCap	–	Motion Capture
MS	–	Microsoft
MSDs	–	Musculoskeletal Disorders
NMB	–	North Malays Basin
NORSOK	–	Norsk Sokkels Konkurranseposisjon (The Competitive Position of the Norwegian Continental Shelf)
NRC	–	Nuclear Regulatory Commission
O&G	–	Oil and Gas
OCA	–	Human Factors
OSHA	–	Occupational Safety and Health Act
P&ID	–	Piping and Instrumentation Diagram
PCSB	–	Petronas Carigali Sdn. Bhd.

PEDG	–	Physical Ergonomics Design Guideline
PETRONAS	–	Petroliam Nasional Berhad
PPE	–	Personal Protective Equipment
PRV	–	Pressure Relief Valve
PTS	–	Petronas Technical Standards
RWP	–	Ranhill WorleyParsons Sdn. Bhd.
SCTA	–	Safety Critical Task Analysis
SD	–	Standard Deviation
SIL	–	Safety Integrity Level
TMI	–	Three Mile Island
UHSE	–	Upstream Business, HSE Division
UK	–	United Kingdom
UKOOA	–	United Kingdom Offshore Operators Association
USDOL	–	United States Department of Labor
USNRC	–	United States Nuclear Regulatory Commission
VCA	–	Valve Criticality Analysis
VICA	–	Valve and Instrument Criticality Analysis
VR	–	Virtual Reality
WHP	–	Wellhead Platform

LIST OF SYMBOLS

A	–	Defuzzification
C1	–	Category 1
C2	–	Category 2
C3	–	Category 3
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., Khafiz, M. N., Abdullasim, N., Ahmad, N., and Dahalan, J. (2022). Conceptual Architecture Development of Virtual Reality – Motion Capture System to Analyze Accessibility and Clearance in Front-End Engineering Design Process: An Exploratory Study. In: Ali Mokhtar, M.N., Jamaludin, Z., Abdul Aziz, M.S., Maslan, M.N., Razak, J.A., *Intelligent Manufacturing and Mechatronics. SympoSIMM 2021*. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-16-8954-3_33

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CHAPTER 1

INTRODUCTION

1.1. Overview

This chapter introduces the basic principle of Human Factors Engineering (HFE) and its long-term benefits to improve human and work performance when implemented comprehensively and effectively during the design of process facilities. This chapter also discusses briefly on the general implementation of HFE approaches globally in comparison to Malaysian process industry focusing on instrument placement designs from HFE point of view. Finally, this chapter also presents the overview of problem statements, research objectives, scope, and questions.

1.2. Human Factors Engineering (HFE)

Human Factors (HF) or ergonomics is the scientific understanding of the relationship between humans and elements in a work system (Grandjean and Kroemer, 1997; Salvendy 2012; IEA, 2017). The term HF and ergonomics can be used interchangeably (IEA, 2017) and covers three domains in a work system, which includes human (anthropometry, biomechanics), task (equipment design, workplace layout), and organizational factors (work culture, communication, teamwork, and many more) (IOGP, 2011; PETRONAS HSE, 2015). Human Factors Engineering (HFE) is the application of HF and ergonomic principles to optimize interaction between human and work systems (Stanton et al., 2005; Johnson and Maddox, 2007; IOGP, 2011; IEA, 2017; Salleh and Sukadarin, 2018). The goal of HFE is to ensure human needs in the workplace are fulfilled through user-centered design, facilitating safe interaction and efficient work performance (Phillips, Repperger, and Reynolds, 2006).

HFE approach considers human anthropometry, biomechanical basis, expected task activities, and other HF principles during the design of a workplace. For example, a valve lever in a chemical plant that requires high activation torque shall be mounted at around operator's elbow height, considering human's maximum grip strength and optimum position for forceful body exertion. Failure to consider human's capabilities and limitations in workplace design is likely to result to inefficient work performance and expose humans to safety and health risks, as evidenced in early HFE implementation approach in late 1960's (Drury, 1997; Kolus et al., 2018). To date, there are several studies conducted to investigate the relationships between workplace ergonomics or HF and its effect on human and work performance. For instance, early study conducted by Wick and Bloswick (1998) has demonstrated the effect of workstation that allows appropriate working posture which resulted in high quality assembly products. More recent study conducted by Gallagher and Heberger (2015) also demonstrated the effect of proper workplace layout and task design that help to reduce internal lumbar loading and resulted to lower safety and health risks on workers.

1.2.1. HFE implementation in global industries

HFE approach, or "fitting the environment to the worker" approach, is not entirely new in the global industries. HFE or ergonomics approach first emerged as a specific discipline in World War II era, where militants (humans) started to operate complex war machines (equipment) (Tilley, 2001; Salvendy, 2012). Over the years, HFE approach has been recognized and applied to all aspects in work systems with human interactions across various industries (Munro and Edmonds, 2016). For instance, in the automotive industry,