

# DEVELOPMENT OF A SPREADSHEET-BASED INITIAL ERGONOMICS RISK ASSESSMENT TOOL USING A DESIGN THINKING APPROACH

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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#### August 2021

Chair Faculty : Professor Shamsul Bahri Mohd Tamrin , PhD : Medicine and Health Sciences

This study intends to develop an Initial Ergonomics Risk Assessment (IERA) spreadsheet in Microsoft Excel using a design thinking approach. This study is divided into three phases. In the first phase, this involves the first and second stage of the design thinking approach which is to empathize and define the problem. This is done through a focus group discussion involving seven groups, with a total of 35 participants. The second phase involves the ideation and prototyping of the spreadsheet tool. This is done through drafts and sketches of the spreadsheet-based IERA tool to generate ideas based on the users' requirements. A prototype was then developed on Microsoft Excel using formulas to automate the calculation of ergonomics risk factors. The final phase involves the testing of the IERA spreadsheet. This was done through comparing the level of agreement of the developed tool against the traditional pen and paper approach in performing an IERA at four different companies in Malavsia covering a total of 20 different work units with different ergonomics risk. Feedback on the tool is obtained from the participants of the focus group discussion to determine if the developed spreadsheet fulfils the user requirements. The first phase determined a total of 21 different types of issues which can roughly be grouped into two large categories which are the needs for convenience and the needs for validity. This information is used to develop the spreadsheet tool in the second phase. The second phase involves using the output of the first objective to design and develop an assessment tool using Microsoft Excel to perform an Initial Ergonomics Risk Assessment. This development covers the Ideate and Prototyping stage of the Design Thinking approach. The spreadsheet developed was developed based on the 19 points raised during the focus group discussion and was incorporated in the spreadsheet. In the third phase, the tool was evaluated at a total of four sites with a total of 20 work units and it was found that the reliability for the IERA spreadsheet was found to be in perfect agreement with the pen and paper method through kappa statistics, and the hypothesis is accepted. Feedback from 7 participants is obtained and it was found that in general the user requirements which were discussed in the focus group

previously is fulfilled. Findings in this study indicates that the IERA tool which was developed can be used to perform an IERA assessment. The Design Thinking approach used in the development of the tool provides an early understanding of user requirements which is then built into the design of the tool which results in positive feedback on the spreadsheet developed. However, further research work should be considered to address the limitation as reported in the study.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

## DEVELOPMENT OF A SPREADSHEET-BASED INITIAL ERGONOMICS RISK ASSESSMENT TOOL USING A DESIGN THINKING APPROACH

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Ogos 2021

#### Pengerusi : Profesor Shamsul Bahri Mohd Tamrin, PhD Fakulti : Perubatan Dan Sains Kesihatan

Kajian ini bertujuan untuk membangunkan hamparan Initial Ergonomics Risk Assessment (IERA) di aplikasi Microsoft Excel dengan menggunakan pendekatan pemikiran reka bentuk. Kajian ini terbahagi kepada tiga fasa. Dalam fasa pertama, ia melibatkan peringkat pertama dan kedua pendekatan pemikiran reka bentuk iaitu untuk memahami dan menentukan masalah. Ini dilakukan melalui perbincangan kumpulan fokus yang melibatkan tujuh kumpulan, dengan seramai 35 peserta. Fasa kedua melibatkan pembentukan idea dan prototaip alat hamparan. Ini dilakukan melalui draf dan lakaran alat IERA dengan menggunakan hamparan untuk menghasilkan idea berdasarkan keperluan pengguna. Prototaip kemudiannya dibangunkan di Microsoft Excel dengan menggunakan formula untuk mengautomasikan pengiraan faktor-faktor risiko ergonomik. Fasa terakhir melibatkan ujian hamparan IERA. Ini dilakukan dengan membandingkan tahap persetujuan alat yang dibangunkan terhadap pendekatan tradisional melalui pen dan kertas dalam melaksanakan IERA di empat syarikat berbeza di Malaysia yang meliputi sejumlah 20 unit kerja yang berbeza dengan risiko ergonomik yang berbeza. Fasa pertama menentukan sejumlah 21 jenis isu yang boleh dikumpulkan kepada dua kategori utama iaitu keperluan untuk kemudahan dan keperluan untuk kesahihan. Fasa kedua melibatkan penggunaan output objektif pertama untuk mereka bentuk dan membangunkan alat penilaian menggunakan hamparan Microsoft Excel untuk melaksanakan Initial Ergonomics Risk Assessment. Hamparan yang dibangunkan itu dibangunkan berdasarkan 19 isu yang dibangkitkan semasa perbincangan kumpulan fokus dan dimasukkan dalam hamparan. Pada fasa ketiga, alat ini telah dinilai di empat tapak dengan sejumlah 20 unit kerja dan didapati bahawa kebolehpercayaan untuk hamparan IERA didapati dalam persetujuan yang sempurna dengan kaedah pen dan kertas melalui statistik Kappa, dan hipotesis diterima.Penemuan dalam kajian ini menunjukkan bahawa alat hamparan IERA yang dibangunkan boleh digunakan untuk melaksanakan penilaian IERA. Walau bagaimanapun, kerja penyelidikan yang lebih lanjut perlu dipertimbangkan untuk menagani had seperti yang dilaporkan dalam kajian.

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Finally, to you. You who flipped to the acknowledgement section and found that the author has dedicated this to someone else and not you. But not this time. Because this one is for you, and your patience for reading this part.

Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Signature:	
Supervisory Committee:	Assoc Prof Dr. Ng Yee Guan

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# LIST OF ABBREVIATIONS

DOSH	Department of Occupational Safety and Health
ETP	Ergonomics Trained Person
IEA	International Ergonomics Association
IERA	Initial Ergonomics Risk Assessment
MAC	Manual Handling Assessment Charts
MSD	Musculoskeletal Disorders
OCRA	Occupational Repetitive Actions
OSH	Occupational Safety and Health
QEAT	Quick Ergonomic Assessment Tool
QEC	Quick Exposure Check
RAMP	Risk management Assessment tool for Manual handling Proactively
RAPP	Rapid Assessment for Pushing and Pulling
REBA	Rapid Entire Body Assessment
RULA	Rapid Upper Limb Assessment
SHO	Safety and Health Officer
socso	Social Security Organization
UPM	Universiti Putra Malaysia

#### CHAPTER 1

#### INTRODUCTION

This chapter provides a brief introduction to the background of the research, which including a discussion on the background of the research which include the problem in the current assessment of risk assessment and justification for the research. The conceptual framework of this research is also presented, followed by the objectives and the hypothesis.

#### 1.1 Research Background

Ergonomics is often used inter-changeably with Human Factors, and this refers to an interdisciplinary science relating to anthropometry, physiology, psychology, engineering and other sciences to ensure that the designs of work can complement the strengths of people and minimize their limitations (Chartered Institute of Ergonomics & Human Factors, 2017), which in turn allow for more efficient workplaces while reducing non-value added activities at the workplace (Santos, Vieira, & Balbinotti, 2015). The International Ergonomics Association (IEA) uses the following as their definition of ergonomics:

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (IEA, 2020).

This definition used by the IEA covers a broad spectrum, inclusive of physical ergonomics, cognitive ergonomics and organizational ergonomics. However, this research covers specifically on physical ergonomics, which is mainly concerned with the how the physical activities at work affect and is affected by the human anatomical, anthropometric, physiological and biomechanical characteristics (IEA, 2020).

One of the most common issues which arise from physical ergonomics are musculoskeletal disorders. Musculoskeletal disorders are injuries related to the human musculoskeletal system, which affect the muscles, nerves, tendons, joints and cartilages in the human body (CDC, 2018). These injuries include carpal tunnel syndrome, epicondylitis, tenosynovitis of the hand and wrists, thoracic outlet syndrome, back pains, and even includes diseases which are caused by vibration (Adisesh, 2013).

Musculoskeletal disorders (MSDs) is an increasing threat for occupational safety and health (OSH) practitioners globally. Increasing MSDs among the industries cause suffering towards the individual in terms of social and economic impact (Foley, Silverstein, & Polissar, 2007) and the economic burden for industries through productivity loss (Hagberg, Vilhemsson, Tornqvist, & Toomingas, 2007) in terms of quality of work, quantity produced, presentism and absenteeism. It is also estimated that lower back pain is ranked highest in terms of disability and sixth in terms of overall burden (Hoy, et al., 2010), and the number of people suffering will increase dramatically over the coming decades (World Health Organization, 2018).

MSDs are caused by various factors, from the workplace from risk factors such as forceful exertions, awkward postures, static and sustained postures, repetitive motion, and exposure to environmental extremes. MSD can also come from personal risk factors such as being overweight, smoking, or being in poor physical shape (Maghsoudipour, Dehghaan, Moghimi, & Rahimpanah, 2008).

In Malaysia, musculoskeletal disorders are not something new, but is a major industrial concern as it has been increasing exponentially. Based on Figure 1.1, the Social Security Organization (SOCSO) has a total of 1354 cases reported in 2017, an increase of 348 cases which is the highest increase in reported incidents in a span of 17 years. This shows that the rate of musculoskeletal disorders is continuing to increase despite efforts to reduce them from the government. However, in 2018, a year after the publication of the Guidelines on Ergonomics Risk Assessment at the Workplace, there is a reduction of cases from 1354 to 1151, showing a possible improvement.



# Figure 1.1: Statistics of Musculoskeletal Disorders Reported to SOCSO from 2000 to 2018

Musculoskeletal diseases are expensive to both the organization and the country. Zein et. al. (2019) performed an analysis of the total direct cost which is paid out by the Social Security Organization of Malaysia (SOCSO) for Malaysian workers due to the onset of musculoskeletal disorders. These costs include the compensation cost, return to work, rehabilitation cost and medical cost. For a

five-year period from 2009 to 2014, the SOCSO has issued out almost RM11 billion for just a total of 416 claimants.

In 2016, the Department of Occupational Safety and Health (DOSH) successfully produced a document outlining their direction and aims for the government to uphold occupational safety and health (OSH) in the country through a comprehensive master plan known as the OSHMP2020. The main strategy for the OSHMP2020 is to develop a preventive culture within the industries in Malaysia, with five strategies which are government leadership, strengthening of OSH management, OSH sharing and network, mainstreaming industrial hygiene and international alliance, which are all aligned to the main strategy (DOSH, 2016).

One of the main programs in the Strategy 4 for the mainstreaming of industrial hygiene involves the re-engineering of industrial hygiene management. This is performed through the establishment of the Systematic Occupational Health Enhancement Level Programme (SoHELP) which is a systematic intervention program to help industries enhance their industrial hygiene standard and meet legal requirements relating to industrial hygiene, specifically looking into issues related to exposure to noise, chemicals and ergonomic risk factors.

#### 1.2 Problem Statement

Ergonomics risk assessments are usually developed in the form of a pen and paper approach where the person performing the risk assessment will assess the workplace using a printed form or checklist and manually calculate the risk in the form itself. Over time, different software-based tools have been created on various platforms including Microsoft Excel. This includes tools for Rapid Upper Limb Assessment (RULA), Manual Handling Assessment Charts (MAC), Occupational Repetitive Actions (OCRA) and Quick Exposure Check (QEC).

Table 1.1 shows a sample of different types of observational methods for performing ergonomics risk assessment and the existence of corresponding software to perform the ergonomics risk assessment.

 Table 1.1: Observational Based Methods of Risk Assessments in Pen and

 Paper and Software form

Assessment Method	Pen & Paper	Software	Software Type
RULA	$\checkmark$	$\checkmark$	Android
RULA	$\checkmark$	$\checkmark$	Microsoft Excel
MAC	$\checkmark$	$\checkmark$	Microsoft Excel
RAMP	$\checkmark$	$\checkmark$	Microsoft Excel

#### Table 1.1: Continued

Assessment Method	Pen & Paper	Software	Software Type
QEC	$\checkmark$	$\checkmark$	Microsoft Excel
OCRA	$\checkmark$	$\checkmark$	Microsoft Excel

These software-based assessments can reduce the process time by more than half, create a structured system and eliminate human error (Kadikon, Shafek, & Bahurdin, 2015). Unlike their pen & paper counterpart, which have various limitations such as cumbersome paperwork, requires time and energy commitments, and manual calculation which are error prone.

Software-based assessments are also beginning to be more accessible at most workplaces in Malaysia as most of the population in Malaysia have access to a computer. A recent survey by the Department of Statistics Malaysia (2008) identified that 70.5% of the population uses a computer and 97.9% uses a mobile phone. Most of these computers and mobile phones have access to spreadsheet application such as Microsoft Excel as they come pre-installed, and oftentimes the use of spreadsheet applications can be found everywhere in almost all levels of an organization (Jannach, Schmitz, Hofer, & Wotawa, 2014).

However, despite the benefits of software-based assessments there is currently no existing tool which is suitable in the Malaysian context where the primary method of performing an ergonomics risk assessment is the "Initial Ergonomics Risk Assessment" method (DOSH, 2020). As such, Malaysian workplaces and OSH professionals are unable to effectively use these readily available assessment tools to assess and control the ergonomics risk at the workplace. The reason for this is that the available tools are not designed for this particular user group but are designed to assess the specific ergonomics risk such as awkward posture, lifting and lowering or repetition, but not to perform the assessment for all types of risk factors at a single time. This would cause users to require multiple tools to perform the assessment instead of a single easy to use assessment tool.

Due to this, it is important to ensure that risk assessment tool for the Initial Ergonomics Risk Assessment method is designed with the users needs in mind. However, the risk assessment tools are generally designed based on methods to assess the risk effectively and accurately and does not consider the user requirements. Using a design thinking approach would be able to allow the development to include an understanding of how the human needs relates to the problem and reframes the problem in a human-centric way (Foster, 2019).

#### 1.3 Study Justification

The main beneficiaries of the developed Microsoft Excel based risk assessment tool would be (1) the Department of Occupational Safety and Health and (2) occupational safety and health practitioners in various workplaces. For both groups, the primary purpose of using an ergonomics risk assessment is the same where it is used to assess the level of risk at the workplace. This information will then be used in slightly different ways where for DOSH the purpose will be for enforcement while for occupational safety and health professionals the purpose will be for improvements.

There are currently a total of 1196 people who are recognized by DOSH to be an Initial Ergonomics Risk Assessment Trained Person (DOSH, 2020) based on the website. However, despite this, there are a total of 1151 cases of MSD claims issued out by SOCSO in 2018, and it is estimated that many more cases of MSDs are not being reported (Yusof, et al., 2019).

The significance of this study is to develop a software-based assessment tool for the Initial Ergonomics Risk Assessment using a Design Thinking approach which would allow the developed tool to be designed based on the needs and requirements of the user. This would result in improved usability and adoption of the tool.

This will allow practitioners in both DOSH and in organization such as the Safety and Health Officers or Occupational Health Doctors will be able to provide better ergonomics insight to the management of the organization, reduce cost in performing assessments and implementation of ergonomics control measures which are targeted to the most relevant ergonomics risk factor present in the workplace. Through these efforts, it is possible to further reduce the number of MSD cases in the workplace.

The developed spreadsheet is expected to make it easy for users to perform an IERA, thus making it possible for proactive assessment of ergonomics risk at the workplace in order to accurately the risk levels of the various work areas in terms of ergonomics risk. Through this, the users will be able to provide insight on the condition to the management. Inadvertently, this would also increase the number of practitioners in the field who can perform their own ergonomics risk assessments and identify ergonomics risk in their own respective workplaces without overreliance on external assessors or consultants, thus reducing the financial impact towards the companies.

Having a tool to simplify the assessment would also reduce the difficulty in performing assessments and also increasing the accuracy of the assessments performed. This would allow organizations to be able to better allocate resources to target relevant risk factors.

# 1.4 Objectives

# 1.4.1 General Objective

The main objective for this study is to develop a spreadsheet based Initial Ergonomics Risk Assessment software using a design thinking approach.

# 1.4.2 Specific Objectives

Specifically, this study seeks to:

- 1. Determine the needs and expectations of possible users of the softwarebased Initial Ergonomics Risk Assessment (IERA) tool;
- 2. Design and develop an assessment tool using Microsoft Excel to perform an Initial Ergonomics Risk Assessment; and,
- 3. Determine the significant difference in the results between the developed software based IERA tool against the traditional pen and paper IERA.
- 4. Determine the suitability, efficiency and usability of the developed software based IERA tool.

# 1.5 Hypothesis

The following Table outlines the hypothesis based on the specific objectives for this study.

#### Table 1.3: Hypothesis for the Research Objectives

Objective	Hypothesis
To determine the needs and expectations of possible users of the software-based IERA Tool.	No hypothesis.
To design and develop an assessment tool using Microsoft Excel to perform an Initial Ergonomics Risk Assessment.	No hypothesis.
To validate the risk assessment score of the software-based IERA Tool against the traditional pen and paper IERA approach.	There are no significant differences in the results between the developed software-based IERA tool against the traditional pen and paper IERA approach.

#### Table 1.3: Continued

Objective	Hypothesis
To determine the suitability,	The developed software-based IERA
developed software-based IERA	based on user feedback.
Tool	

## 1.6 Conceptual Framework

The conceptual framework in Figure 1.2 shows the various elements which are considered during the development of the spreadsheet-based IERA tool which utilizes the design thinking approach proposed (Brown, 2008) as the basis of the development process. This process is split into five stages which is the empathize, define, ideate, prototype and test stages respectively.

In the first and second stage which makes up the first phase of the study, the user needs are required to be understood and defined in order to serve as inputs in the development of the software in the second phase of the study. There are three types of user needs which are classified based on ISO 9421-210:2019 (2019) which are implied, stated and unaware. In this study, the user needs which are implied and stated are used as inputs, leaving out those which are unaware. The reason behind this is that the method required to understand and obtain the needs which are unaware by the users will take up substantial amount of time and resources which is not available during this study. Although this would lead to some limitation in the developed software, the main implied and stated needs from the users should provide sufficient information in order to develop a functioning software to perform an initial ergonomics risk assessment.

The second phase of the study would cover the ideate and prototype stage of the design thinking approach. Through the identification of needs from the first phase, the prototype can then be developed by ideating the ideas using sketching. This will allow the generation of large quantity of ideas so that the best and most practical idea can be selected to be developed into a prototype.

The final stage for the design thinking approach would be the testing phase. Based on system software quality based on the ISO 9241-220 (ISO, 2019) they are respectively functional suitability, performance efficiency, compatibility, maintainability, security, reliability and usability. In this particular study, we will be mainly focused on the suitability, efficiency, usability and reliability of the developed tool to assess ergonomics risk based on the IERA method.



# Figure 1.2: Conceptual Framework on Design and Development of IERA Spreadsheet Tool using Design Thinking Approach

# 1.7 Organisation of the Thesis

This thesis is organised into five main chapters.

The first chapter provides an introduction and overview of the whole study, providing some background information and literature regarding the issues faced by practitioners who are performing an initial ergonomics risk assessment at the workplace and the justifications for the development of a software-based tool to aid in performing the assessments.

The second chapter provides an overview of the literature surrounding the design thinking approach, which is the selected method for the development of the software-based tool. This chapter also explores the various types of spreadsheet-based software which are relevant to ergonomics risk assessment, and those which are not relevant but is still able to provide design ideas to enhance the ideation process.

The third chapter discusses the methodology for the development of the spreadsheet-based IERA tool, which is divided into three main phases which is based on the five-stage model of the design thinking approach. In the first phase, the empathise and define stages are discussed, in the second phase, the development of the tool would consist of the ideate and prototype stage, and lastly the third stage covers the testing phase of the design thinking approach.

The fourth chapter presents the findings of the study and discusses the findings in the context of the literature which was reviewed. These findings are presented in the three phases based on the third chapter, covering all five stages of the design thinking approach.

The fifth chapter outlines the conclusion of the study and presents the contribution from the study, discusses the limitations for the current study, and recommendations for further studies on the subject matter.

## 1.8 Chapter Summary

This chapter outlines a brief introduction of the background of MSD cases in Malaysia and the issues related to pen and paper assessments against softwarebased assessments. The importance of this research has also been discussed, with objectives and relevant hypothesis for this study being specified. In this chapter, the conceptual framework was also presented.

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