UNIVERSITI TEKNOLOGI MARA

# THE FRAMEWORK OF ERGONOMIC RISK AMONG THE TRADES AT CONSTRUCTION SITE IN MALAYSIA

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MSc

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# UNIVERSITI TEKNOLOGI MARA

# THE FRAMEWORK OF ERGONOMIC RISK AMONG THE TRADES AT CONSTRUCTION SITE IN MALAYSIA

**NAELA UDANI BINTI SUAINBON**

Thesis submitted in fulfilment
of the requirements for the degree of
**Master of Science**
**(Built Environment)**

**Faculty of Built Environment**

**August 2026**

# CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 1 April 2026 to conduct the final examination of Naela Udani Binti Suainbon on her Masters of Science thesis entitled "The Framework of Ergonomic Risk Among the Trades at Construction in Malaysia" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

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# ABSTRACT

Working conditions in the construction sector are highly accident-prone, with numerous ergonomic risks involved. Tradespeople are exposed to significant amounts of various hazards that could lead to bodily harm or even death. They also encounter a wide range of safety and health risks on site, including repetitive or awkward postures, thermal stress, loud noise, vibrations, and more. The greater the exposure to this risk either individually or in combination the higher the likelihood of ergonomic harm or the development of Work-related Musculoskeletal Disorders (WMSDs). The objectives of this study are to identify ergonomic risks, investigate the effects of these risks towards trades, investigate improvement of Ergonomic Risk and development of Conceptual Framework of Ergonomic Risk at construction site. To achieve these objectives, semi-structured interviews, document analysis, and a questionnaire survey were conducted with professionals and tradespeople from selected residential projects. Additionally, a validation process involving experts was performed. Ten (10) respondents were selected for the semi-structured interviews, but only eight (8) agreed to participate. A total of 196 questionnaires were distributed to tradespeople, with 80 completed responses returned. Furthermore, eight (8) expert panel members were chosen for the validation process. Findings revealed that repetitive or awkward postures, highly repetitive tasks, and exposure to extreme temperatures are the most significant ergonomic risks faced by construction workers. Consequently, the lower back, shoulders, upper back, and wrists or hands are the most commonly affected body areas, often resulting in pain and discomfort. To mitigate ergonomic risks on construction sites, workers should receive proper induction and training before commencing work, and employers must implement adequate safety and health measures. The adoption of Industrial Revolution 4.0 initiatives also supports productivity enhancement, industry modernization, and improved site safety. Finally, the expert panel confirmed that the proposed conceptual framework is appropriate. The outcomes of this research are intended to support improvements in essential safety procedures and workplace regulations, raise awareness among tradespeople, and provide supplementary data for relevant authorities.

# ACKNOWLEDGEMENT

In the name of Allah S.W.T the most gracious and most merciful, with his permission Alhamdulillah this study has been completed. Raise to Prophet Muhammad S.A.W., His companions and to those on the oath as what He preached upon, might Allah Almighty keep us His blessing and tenders.

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Finally, this thesis is dedicated to the loving memory of my very dear late father and my lovely mother for the vision and determination to educate me. This piece of victory is dedicated to both of you. Alhamdulillah.

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# LIST OF ABBREVIATIONS

**Abbreviations**

| | |
|---|---|
| BIM | Building Information Modelling |
| CIDB | Construction Industrial Development Board |
| DOSH | Department of Occupational Safety and Health |
| ERF | Ergonomic Risk Factors |
| IoT | Internet of Things |
| LBP | Low Back Pain |
| NCP | National Construction Policy |
| OSH | Occupational Safety and Health |
| PPE | Personal Protective Equipment |
| SDGs | Sustainable Development Goals |
| WMSD | Work-related Musculoskeletal Disorder |

# CHAPTER 1
# INTRODUCTION

## 1.1 Research Background

The construction industry is one of the major sectors that significantly contributes to Malaysia's economic growth. Despite, its environment can cause the accident prone also well-known as most hazardous sector whereas building workers are exposed to excessive site construction dangerous that may end in injuries or perhaps death (Abdul Halim et al., 2020).

Anagha and Xavier (2021) also stated that, Construction Industry is one of the fastest sectors growing in the world and workers are an essential part of this sector. Accidents in the construction industry are caused by the sector's unique character, human behaviour, poor site conditions, hazardous work activities, equipment, and procedures, all of which are influenced by lack of safety management. Abas, Yusuf, Suhaini, Kariya, Mohammad and Hasmori (2020) found that major construction projects in Malaysia are subjected to hazardous circumstances, which can result in accidents and, as a result, damage the safety performance of the projects.

Construction workers are the ones that perceive the lack of job safety the most (Anagha & Xavier, 2021). According to Department of Statistic Malaysia (2023) shown that the construction sector is one of the most dangerous workplaces, with high rates of deaths, injuries, and health issues. Due to unique character, hazardous in construction site may result in accidents, causing extra disruption and limiting the work rate. Thus, it's challenging for ergonomic aspects to be implemented on site (Shakil Ahmed, 2019).

Ergonomics defined as science-based discipline that brings together knowledge from other subjects such as anatomy and physiology, psychology, engineering and statistics to ensure that designs complement the strengths and abilities of people and minimize the effects of their limitations. Rather than expecting people to adapt to a design that forces them to work in an uncomfortable, stressful or dangerous way, ergonomists and human factors specialists seek to understand how a product, workplace or system can be designed to suit the people who need to use it (Hassanain, 2024).

Research consistently shows that construction workers face high ergonomic risk due to heavy material handling, repetitive tasks, awkward postures, vibration, and contact stress, all of which contribute to WMSDs (Badger et al., 2020; Mekkodathil et al., 2020). Work-related musculoskeletal disorders (WMSDs) refer to injuries and disorders affecting muscles, tendons, ligaments, joints, nerves, and other musculoskeletal structures that develop as a result of occupational exposures and work activities. WMSDs are commonly associated with repetitive movements, forceful exertions, prolonged static work, and awkward postures, which may lead to pain, discomfort, functional limitations, and reduced work performance (Hamid & Hilmi, 2022; Lim et al., 2021).

Construction workers are regularly exposed to ergonomic hazards, including heavy lifting, repetitive movements, vibration, and sustained awkward postures, which are significant contributors to work-related musculoskeletal disorders and may increase accident risks by impairing workers' physical performance and situational awareness; similar findings have been reported in Malaysia, where these ergonomic stressors are prevalent across various construction trades and are strongly associated with musculoskeletal health problems (World Health Organization & International Labour Organization, 2022; Abas et al., 2018; Lop et al., 2019)

According to DOSM (2024), Malaysia reported a 13.8% rise in occupational injury cases, totaling 38,950 cases compared to 34,216 cases in 2022. Consequently, the occupational injury rate per 1,000 workers increased to 2.46 from 2.26 in the previous year. Additionally, the number of non-fatal occupational injury cases also rose to 38,626 cases from 33,899 cases in 2022 as shown in figure 1.1. Therefore, in this research, the significance of ergonomic risk among the trades at construction site will be deliberated meticulously.

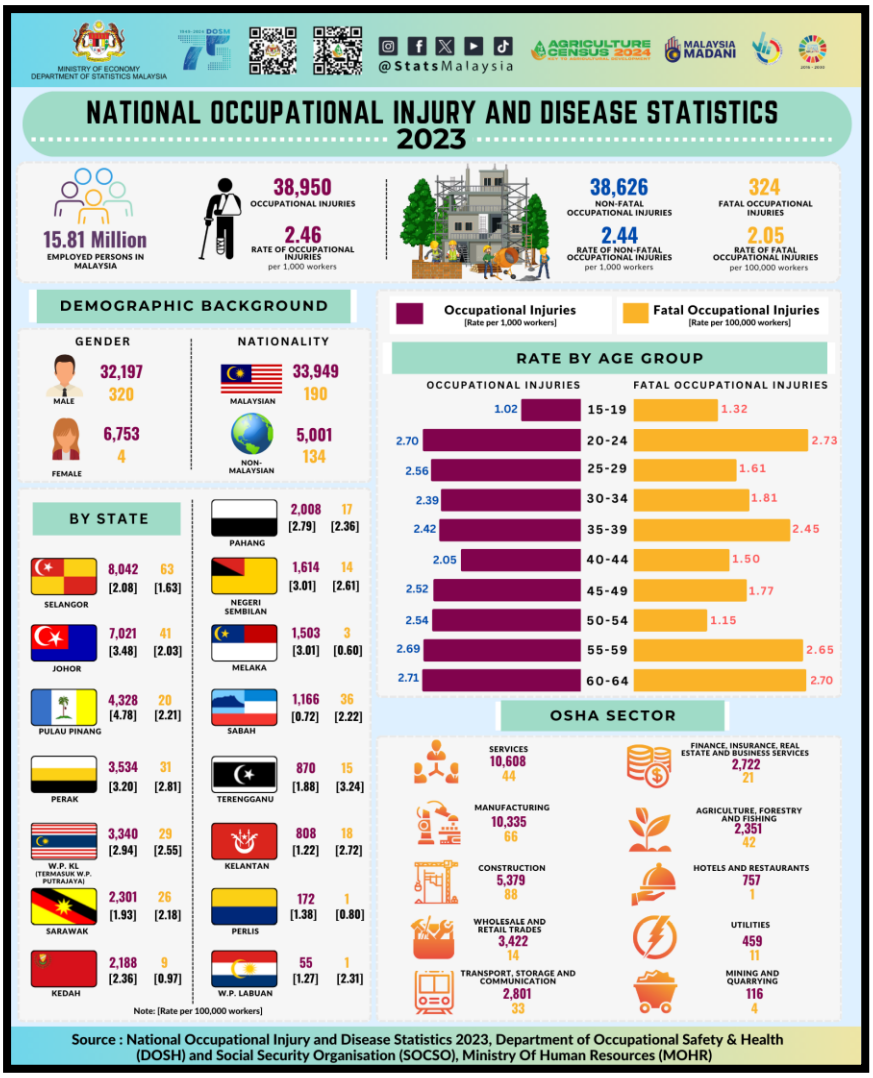



Figure 1.1 NationalOccupational Injury and Disease Statistic

## 1.2 Problem Statement

The construction industry is one of the most important sectors contributing to economic development; however, it is also recognized as one of the most hazardous industries worldwide. Construction workers are frequently exposed to various occupational hazards, including dust, excessive noise, vibration, thermal stress, and physically demanding work environments (Vijayakumar & Choi, 2022). These hazardous conditions increase the likelihood of workplace accidents, injuries, and occupational diseases, making the construction sector particularly vulnerable to safety and health issues. Despite continuous efforts to improve occupational safety and health (OSH) practices, construction sites continue to record high rates of work-related injuries and fatalities compared to many other industries.

Among the various occupational hazards, ergonomic risk factors have emerged as a major concern in the construction industry. Construction activities often require workers to perform manual handling tasks, lift heavy loads, adopt awkward body postures, perform repetitive movements, and work with vibrating tools. Prolonged exposure to these ergonomic stressors can lead to work-related musculoskeletal disorders (WMSDs), including strains, sprains, and other musculoskeletal injuries (Vijayakumar & Choi, 2022). As construction work is highly labor-intensive, poor ergonomic practices remain prevalent and continue to expose workers to significant physical risks. Furthermore, employee attitudes and safety behaviour have been identified as critical factors influencing workplace safety performance. Inadequate safety awareness and unsafe work practices may further increase workers' exposure to ergonomic hazards and occupational injuries (Shakil Ahmed, 2019).

The consequences of ergonomic risks extend beyond workers' physical health and significantly affect organizational performance. WMSDs can result in pain, disability, reduced work capacity, absenteeism, and increased healthcare costs. Workplace accidents and injuries may also lead to project delays, increased operational expenses, reduced productivity, and financial losses for construction companies (Abdul Aziz et al., 2020). In addition, poor workplace health and safety management can increase insurance premiums, legal penalties, employee turnover, and overall employment costs (Abdul Aziz et al., 2019). Previous studies have emphasized that safe and healthy working environments not only protect workers but also enhance productivity, efficiency, worker morale, and overall organizational performance. Therefore, effective ergonomic management is essential for ensuring both worker well-being and project success.

In recent years, researchers have explored the potential of Industry 4.0 technologies, such as Building Information Modeling (BIM), wearable sensors, smart helmets, Internet of Things (IoT) applications, augmented reality, and exoskeletons, to improve construction safety and ergonomic performance (Tomasz Małysa et al., 2024). However, the implementation of these technologies remains challenging due to high investment costs, infrastructure requirements, resistance to change, limited training opportunities, and the absence of comprehensive implementation frameworks (Satyro et al., 2021). Moreover, although existing ergonomic assessment methods primarily focus on posture-related risks, they often overlook other important factors, including

individual worker characteristics, task-related factors, and environmental conditions (Satyro et al., 2021).

Recent research by Tao et al. (2024) proposed an ergonomic risk assessment framework that incorporates task, individual, and environmental factors affecting construction workers. Nevertheless, the relative importance and prioritization of these ergonomic risk factors have not been systematically investigated. Existing studies also highlight the limited integration of multiple ergonomic dimensions within a comprehensive assessment framework, creating a gap in understanding the complex interactions among ergonomic risk factors in construction environments.

Therefore, there is a need to develop a comprehensive ergonomic risk framework that systematically identifies and evaluates the critical ergonomic risk factors affecting construction workers. Such a framework would provide a comprehensive understanding of ergonomic hazards within construction sites and support the development of effective intervention strategies to improve worker safety, health, and productivity. Consequently, this study aims to propose a comprehensive ergonomic risk framework for construction sites that can assist industry stakeholders in enhancing ergonomic management and reducing the occurrence of WMSDs.

## 1.3 Research Aim and Objectives

The aim is to propose framework of ergonomic risk factor among the trades at construction site in Malaysia.

The specific objectives of the research are outlined as follows:

a) To investigate ergonomic risk factors among trades at construction site.

b) To identify the effects of ergonomic risk factor on workers in selected construction trades.

c) To determine improvement measures for reducing ergonomic risk factor at construction site.

d) To develop a framework for managing ergonomic risk factor at construction site

## 1.4 Scope of the Research

The research involved the construction site in Malaysia and focused in the Selangor (Klang & Shah Alam) area due to enormous contribution in residential building and civil engineering sub sectors. Four (4) numbers on going residential project will be chosen from that area. According to Hassanudin Mohd (2023), Malaysia's housing market has traditionally been an important economic sector. Correspondingly, DOSM reported that residential and civil engineering projects continue to drive construction sector growth, with civil engineering contributing more than 40% of the total value of construction work completed in 2023. Given that Selangor consistently records the highest construction work value in the country, the state was deemed an appropriate setting for this study.

Respondents were purposively selected from among skilled and semi-skilled construction workers who possessed practical knowledge and experience related to ergonomic practices on construction sites. The selected trades included workers engaged in activities such as material handling, formwork installation, reinforcement work, bricklaying, concreting, electrical installation, and plumbing. These workers were chosen because their daily tasks frequently involve exposure to ergonomic risk factors, including heavy lifting, repetitive movements, forceful exertions, vibration, and awkward working postures. Consequently, their experience and awareness of workplace ergonomic conditions enabled them to provide informed responses regarding the prevalence of ergonomic hazards and the effectiveness of existing control measures within the construction environment.

To collect the data, probability sampling method by Krejcie and Morgan (1970) will be used. Eighty (80) numbers of respondents will be collected as data in each project and cluster sampling technique used for the selected trades. While for the semi structure interview Ten (10) respondents will be selected. The most important, the study will cover the ergonomic risk factor that they have been through.

## 1.5 Significance of the Research

Safety consciousness is a continual awareness that every worker should have at all times. It includes being constantly aware of how they work and being able to identify the risk they encounter. Thus, it is important to implement this research. The significance of the research is outlined as follows:

a) To ensure workers have the necessary safety procedures and regulation in workplaces.
b) Able to control or eliminate risk, the consequences and/or likelihood of illness, injury and death are reduced.
c) To provide additional data to CIDB and OSHA for eliminate risk factor.
d) Develops a comprehensive ergonomic risk framework for construction trades in Malaysia construction industry.
e) Enhances organizational performance by reducing ergonomic-related health issues, work disruptions, and productivity inefficiencies.

## 1.6 Research Methodology

Figure 1.2 shows the research process. The research process is divided into five (5) phases.

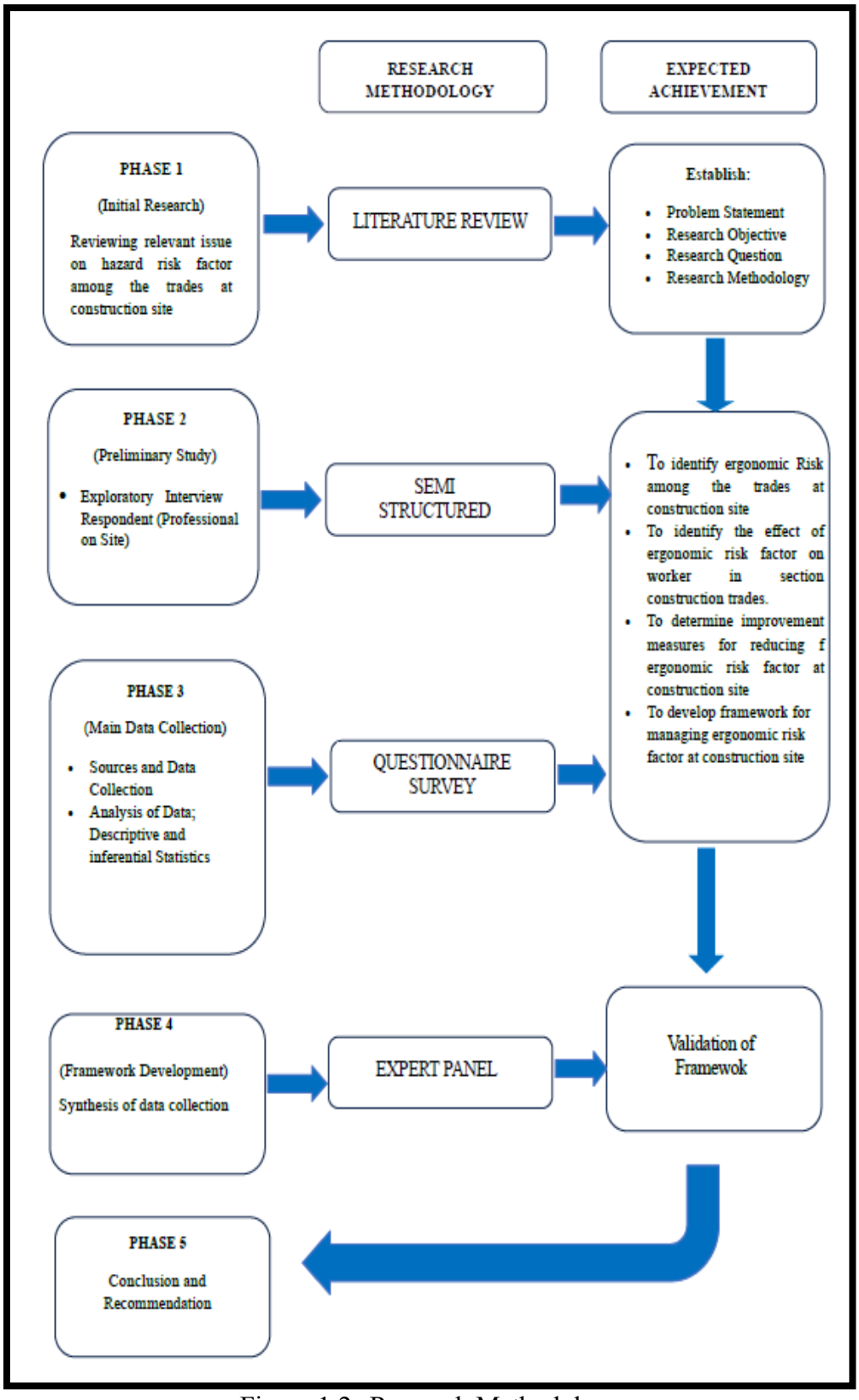



Figure 1.2 Research Methodology

a) Phase 1

In this phase relevant issue regarding ergonomic hazard risk will be review with the literature search. Based on this research, problem statement, research aim and objectives are established.

b) Phase 2

Phase 2 is the preliminary study, which involves semi-structured interviews and document analysis. The semi-structured interviews aim to understand ergonomic risk from the perspective of industry professionals.

c) Phase 3

Phase 3 focuses on the main data collection process. It builds upon the findings from Phase 1 and Phase 2. In this phase, a questionnaire survey will be administered to selected trades, including bricklayers or masons, concreting workers, roofers, and painting or plastering workers. The collected data will then be analysed using descriptive and inferential statistics with SPSS.

d) Phase 4

In this phase, the collected data will be synthesized, a conceptual framework will be developed, and expert panels will be selected to validate the framework.

e) Phase 5

At last, but not least phase 5. Conclusion and recommendation will be identified in this phase.

## 1.7 Thesis Layout

This thesis consists of five (5) chapters as follows:

*Chapter 1: Introduction*

This chapter outlines the background and main content of the thesis. It introduces the topic, research theme, the nature of the problem under investigation, and the rationale behind the study. The aim and objectives are clearly defined, along with the research methodology chosen to accomplish them. A summary of the stages involved is also provided.

*Chapter 2: Literature Review- Ergonomic Risk among the trades at construction site*

Chapter two presents a literature review on ergonomic risk among the trades at construction site. In this chapter, effect of ergonomic risk to construction industry will be identified. Apart from that, the relation ergonomic risk between construction 4.0 are also highlighted.

*Chapter 3: Research Methodology*

This chapter details the research methodology and methods in carrying out the research. The research samples, interview questions design, questionnaire design and selection of the research respondents are discussed. The research method consists of four main research steps: (1) Literature review; (2) Preliminary Study by means of semi structured interviews; (3) Main data collection - Questionnaire survey; and finally, the (4) Development of the Framework Ergonomic Risk among the trades at construction site. For the development of the framework, expert panel was selected for the validation.

*Chapter 4: Data Analysis and Findings of Preliminary Study and Questionnaire Survey*

Chapter four reports on the findings of the Preliminary Study and Data Analysis of Questionnaire Survey. Preliminary study includes the result of exploratory interviews. The initial data collection is by means of open-ended and semi structured interview questions to ten (10) respondents that are involved with the construction industry. Data Analysis of Questionnaire survey presents a detailed statistical analysis of the data collected from the questionnaire survey. Out of the 196 questionnaires distributed to trades within the construction sites, 80 were returned. Apart from that eight (8) expert

panel also selected for the validation of the framework.

*Chapter 5: Conclusion, Recommendations and Further Research*

Chapter is the final chapter of this thesis and summarise the research work covering all the phases of the research process. It also evaluates the process in relation to the research questions and objectives; contributions, and concludes the research work. The key research findings are presented and discussed, and areas for further research are proposed. The research perspective on the subject researched was highlighted at the conclusion of the chapter.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

The second chapter will review issues related to ergonomic risk at construction site. Firstly, this chapter review of construction industry in Malaysia. Following that, ergonomic issue of ergonomic that lead to WMSD. The next part review on ergonomic risk in construction site, the effect of ergonomic risk and improvement of ergonomic risk in construction site. Finally, this chapter will develop framework of ergonomic risk based on the literature review.

## 2.2 Construction Industry

In recent years, globalization has driven countries to compete internationally, deeply affecting the economy, politics, culture, and environment especially in the construction sector. Alaloul et al (2021) stated that construction sector acts as a backbone of the economic growth of any country, therefore, it influences every sector's role on all levels in an economy. This is supported by Malaysia's National Statistic Organization as shown in the data chart below in Figure 2.1. Figure 2.1 shows that Gross Domestic Products (GDP) by construction sector is the highest percentage 17.3% in 2nd quarter 2024.

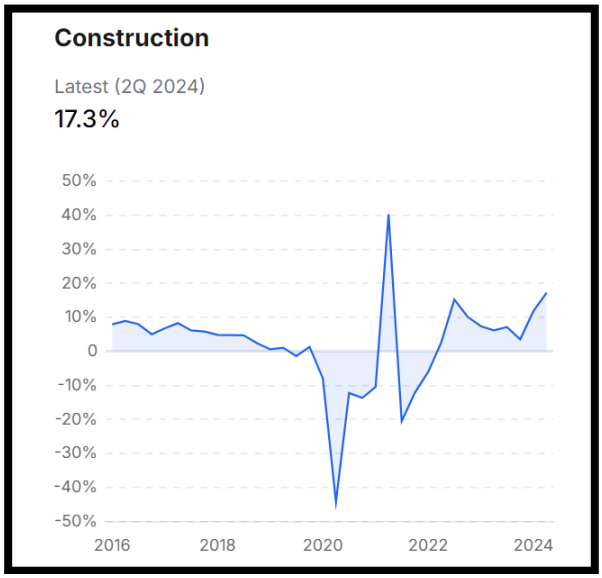



Figure 2.1 Gross Domestic Product by Malaysia's National Statistic

### 2.2.1 Nature of Construction Industry

According to Halim et al. (2020), working in the construction industry requires a diverse set of skills and involves a challenging work environment. The construction industry is recognized as one of the key sectors contributing to Malaysia's economic growth and national development. Despite being among the top three economic sectors in the country, the industry continues to record a high fatality rate due to the inherent hazards associated with construction activities. Furthermore, the construction sector is widely regarded as one of the most hazardous industries worldwide. Figure 2.2 presents the Occupational Accident Statistics by Sector from January 2023 to October 2023, as reported by the Department of Occupational Safety and Health (DOSH) Malaysia. The data indicate that the construction and manufacturing sectors recorded the highest number of fatalities, with 45 death cases each

**OCCUPATIONAL ACCIDENT STATISTICS BY SECTOR JANUARY- OCTOBER 2023 (REPORTED TO DOSH ONLY)**

| SECTOR | NPD | PD | DEATH | TOTAL |
|---|---|---|---|---|
| Hotel and Restaurant | 176 | 0 | 0 | 176 |
| Utilities (Electricity, Gas, Water and Sanitary Service) | 147 | 0 | 4 | 151 |
| Finance, Insurance, Real Estate and Business Services | 554 | 15 | 15 | 584 |
| Construction | 106 | 8 | 45 | 159 |
| Transport, Storage and Communication | 326 | 7 | 9 | 342 |
| Manufacturing | 3,961 | 175 | 45 | 4,181 |
| Wholesale and Retail Trade | 145 | 2 | 0 | 147 |
| Public Services and Statutory Authorities | 117 | 2 | 0 | 119 |
| Mining and Quarrying | 23 | 1 | 4 | 28 |
| Agriculture, Forestry and Fishery | 1,020 | 25 | 19 | 1,064 |
| TOTAL | 6,575 | 235 | 141 | 6,951 |

LEGEND:
PD - PERMANENT DISABILITY
NPD- NON PERMANENT DISABILITY

Figure 2.2 Occupational Accidents Statistic (2023)

Anagha and Xavier (2021) also noted that the construction industry is one of the fastest expanding in the world, and workers are an important part of it. Construction workers are the most likely to perceive a lack of occupational safety. A number of studies have found that the construction industry is one of the most dangerous, with high rates of fatalities, injuries, and health problems. Abas et al. (2020) discovered that significant construction projects in Malaysia are susceptible to hazardous conditions, which can lead to accidents and, as a consequence, degrade the project's safety performance. Hamid et al. (2019) indicated that accidents in the construction industry are caused by the industry's distinct characteristics, human behaviour, bad site conditions, hazardous work activities, equipment, and processes, all of which are impacted by a lack of safety management. These issues may lead to accidents,

generating more disturbance and restricting productivity. As a result, it is difficult to implement safety measures on-site.

### 2.2.2 General Occupational Risk

The construction industry is exposed to numerous occupational risks that may adversely affect workers' health and safety. These risks include physical hazards such as falls, struck-by incidents, electrocution, and noise exposure, together with ergonomic hazards associated with manual handling, repetitive movements, and awkward working postures. Workers may also encounter chemical, biological, and psychosocial hazards that contribute to occupational injuries and illnesses. Given the hazardous nature of construction activities and the relatively high rate of workplace accidents reported in Malaysia, effective risk management and safety control measures are crucial to minimizing occupational risks and enhancing worker well-being (DOSH, 2017; DOSM, 2023).

## 2.3 Ergonomic Risk Factor in Construction

Ergonomic risks are factors in the workplace that can lead to musculoskeletal disorders (MSDs) or other injuries due to poor ergonomic practices. The three major ergonomic risk factors are force (how much you lift/push/pull), repetition (how frequently you conduct the operation), and posture (body position) (Lop, Mat Salleh, Yop Zain & Saidin, 2019). Other ergonomic risk concerns include vibration, contract stress, prolonged exertion, and frigid temperatures. Typically, workers in the construction industry suffer from MSD but are unaware that they having it (Lop et al., 2019). Anagha and Annie (2020) in their studies also agreed that the main ergonomics risk factors were uncomfortable posture, repetitive movements, and vibration. Other ergonomic risks include unpleasant static positions, muscle and tendon contact, and severe temperatures.

Additionally, according to Lop et al. (2019) the primary characteristics of ergonomic risk factors (ERF) include repetition, force, uncomfortable posture, vibration, contact stress, static loading, and exposure to extreme temperatures. Continuous exposure to these risk factors can lead to the onset of physical symptoms, which may cause long-term damage and significantly reduce the quality of life. Every

work involves risk and the key issue is relative risk. This research discusses the following Ergonomics Risk Factors (ERF) as per shown in table 2.1.

Table 2.1
Ergonomic Risk Factors (ERF) and Related Trades

| ERGONOMIC RISK /TRADES | Repetition / Awkward | Forceful | Static / Sustained Exertion | Vibration | Contract Stress | Temperature |
|---|---|---|---|---|---|---|
| Masonry / Bricklayer | √ | √ | √ | √ | √ | √ |
| Concreting | √ | √ | √ | √ | √ | √ |
| Roofing | √ | √ | √ | | √ | √ |
| Painting / Plastering | √ | | √ | | | |
| Plumber | √ | | √ | | | |
| Electrician | √ | | √ | √ | | |
| General Workers | √ | √ | √ | | | |

Note. Data compiled from Lop et al., (2019) and Anagha and Annie (2020)

### 2.3.1 Definition of Ergonomics

Ergonomics defined as science-based discipline that brings together knowledge from other subjects such as anatomy and physiology, psychology, engineering and statistics to ensure that designs complement the strengths and abilities of people and minimize the effects of their limitations (International Labour Organization., 2024). Rather than expecting people to adapt to a design that forces them to work in an uncomfortable, stressful or dangerous way, ergonomists and human factors specialists seek to understand how a product, workplace or system can be designed to suit the people who need to use it (Centre for Occupational and Environmental Health, 2020). According to Chao fan et. al (2024), in the construction industry, the term 'ergonomics' refers to planning construction activities, supplying tools and supplies, and arranging labor to ensure worker safety and health. A practical ergonomics program has to suit the worker and the task. Work techniques, equipment, and tools should be developed to accommodate workers' physical and mental capacities, as well as the surroundings, including noise, temperature, and exposure to prevent twisting and bending.

According to Francis & Deepan (2019), Ergonomic risks on construction sites can result in severe and traumatic joint and muscle injuries. Exposure to a single risk factor or a combination of risk variables increases the possibility of ergonomic injury

or illness, commonly known as Work Related Musculoskeletal Disorders (WMSD) They can lead to long-term and serious medical issues that prevent individuals from working and enjoying life (Francis & Deepan, 2019). Musculoskeletal disorders are a major concern resulting from construction workers. A good working environment is important since it influences the overall productivity of the construction. Strains, sprains, and work-related musculoskeletal disorders (WMSD) are the most common ergonomic concerns in the construction industry (Dong et al., 2019). These are caused by carrying large loads, repeated actions, awkward postures, and contact stress vibrations. Ergonomics seeks to enhance workplace and environment to reduce the risk of accident or harm. (Dong et al., 2019)

### 2.3.2 Key Ergonomic Risk factor

Construction workers are exposed to several ergonomic risk factors during their daily tasks. These factors can affect the body and may lead to musculoskeletal problems if not properly controlled. The main ergonomic risk factors found in construction work include repetition and awkward postures, forceful or sustained exertions, static positions, vibration, contact stress, and temperature.

#### *2.3.2.1 Repetition / Awkward*

Repetitive motion involves repeated movements of the same group of joints and muscles too frequent, too quickly and over a long duration. A job is considered highly repetitive if the cycle time is 30 seconds or less. Tasks with repetitive movement usually involve other risk factors such as fixed body position and force (Ndiwa, 2019). Awkward posture refers to positions of the body while performing work activities that deviate significantly from the neutral position. Examples of awkward postures are bending, over reaching, working with the hands above the head, elbows above the shoulders, working with the neck or back bent more than 30 degrees without support and lack ability to vary postures (Ndiwa, 2019).

Muscle fatigue may result from prolonged use and overextension of specific muscle groups brought on by repetitive, identical, or comparable activities. It's interesting to note that symptoms frequently relate to the stabilizing or antagonistic tendon and muscle groups that are employed to position and stabilize the extremity in

space rather than the tendon and muscle groups involved in repetitive motions. Muscle groups can occasionally have periods of activity interspersed with rest periods due to task variation, which may help lower the risk of injury (Lohne et al., 2020).

Furthermore, Lohne et al. (2024) also indicate, the position of various body parts is referred to as posture. When you have an unusual posture, your muscles, tendons, and ligaments have to work harder and may be under stress. When any joint in your body bends or twists excessively, beyond a comfortable range of motion, it can result in awkward posture. As well as when a worker must do tasks involving body segments outside of their neutral range while maintaining a deviated posture, the risk of injury increases. Reaching, twisting, bending, kneeling, crouching, working overhead with your hands or arms, and maintaining fixed positions are examples of awkward posture. Neutral posture for the upper arm and shoulder region is relaxed, with arms at the sides and shoulders down and in the same plane.

Anagha and Annie (2021), in their studies REBA assessment identified that the shoulders, knees, legs and back were at a high risk for developing MSDs due to the abducted lower-body postures, the repeated actions and the flexion and extension of the upper limbs. It was also observed that along with incorrect and awkward working posture, certain factors like poor coupling, unstable base, static postures and repetitive actions also contributed to these high-risk levels. They also agreed that masonry or bricklayer and concreting were high risk on the awkward posture and repetitive ergonomic risk.

#### *2.3.2.2 Forceful / Sustained Exertions*

Forceful exertion involves the use of high-level force while transporting or supporting load, including lifting, lowering, pushing, pulling, carrying and moving a load using hands or through the application of bodily force. Forceful exertion can also exist in sustained postures which place excessive force and joints and overload the muscles and tendons (Ndiwa, 2019). Whilst**,** OSHWiki (2020), indicated that, task forces can be thought of as the physical attributes connected to an object or objects outside the body (such as the weight of a box, the pressure needed to activate a tool, or the pressure needed to snap two pieces together) or as the result of an exertion on internal body tissues (such as compression on a spinal disc from lifting, tension within a muscle/tendon unit from a pinch grasp). In general, the degree of danger increases

with the force. High force has been linked to an increased risk of damage to the hand, wrist, forearm, shoulder, neck, and low back.

#### *2.3.2.3 Static / Sustained*

Static or sustained posture refers to minimal or restricted or no movement where the body held on to a particular position over a long period. Maintaining a fix posture can leads to fatigue, pain and injuries which give rise to various disorders. Among the most common examples are prolonged standing and sitting. Prolonged sitting refers to any work activities involving sitting position. However, the duration is subjective, and may vary depending on the assessment of the trained person (Ndiwa, 2019). Also, static loading can be defined in many different ways, but in general, it refers to performing a task for an extended period of time from a single postural posture. Force, posture, and duration all play a part in the disease. The degree of risk is proportional to the interaction of duration, uncomfortable posture, and external resistance magnitude (Health and Safety Executive, 2020).

#### *2.3.2.4 Vibration*

Vibration includes whole-body kinetic vibration (WBV) and hand-arm vibration (HAV). WBV refers to the kinetic energy which is mechanically transmitted through the seat or feet of employees such as driving mobile machines or other work vehicles, over rough and uneven surfaces. HAV refers to the exposure of the hands and arms to kinetic energy from vibrating and percussive hand-held power tools (Ndiwa, 2019). Body tissues can break down as a result of either prolonged resonance or absorption of high energy vibrations, and organs can sustain harm by being buffeted by high vibration levels at relatively low frequencies. A vascular insufficiency of the hands or fingers (also known as Raynaud's disease or vibration white finger) can result from vibration applied to the hand. Additionally, it may disrupt the signal from sensory receptors, increasing the force required to keep the instrument in the hand. Additionally, segmental vibration and carpal tunnel syndrome have been found to be strongly correlated. Usually, using power tools is linked to hand-arm vibration (HAV). When vibrations from the tool are transferred to the hand and arm, exposure takes place (Ndiwa , 2019).

#### *2.3.2.5 Contact Stress*

Contact stress can be internal or external. Internal contact stress refers to a condition when a tendon, nerve or blood vessel is stretched or bent around a bone or tendon. External contact stress refers to a condition when part of the body rubs against a component of the workstation, such as the chair seat pan or edge of the desk (DOSH, 2024). In accordance with Wellnomics (2020), When a sharp or hard object touches the skin, local contact stress is created. The pressure has the potential to harm the tissues and nerves beneath the skin. Activities that can cause local contact stress include the following:

a) Hard edges and ridges on tool handles that dig into the hand

b) Work surface edges that dig into the wrist or forearm

c) Using the hand, foot, or knee to strike objects sharply (for example, using the area above the knee to strike the carpet stretcher when laying carpet).

Effects Stress can worsen when a hard object comes into touch with a region like the wrist, palm, or fingers that has little protecting tissue. It can also worsen when pressure is applied frequently or maintained for an extended period of time.

#### *2.3.2.6 Temperature*

Extreme temperatures can impact an employee's body temperature, resulting in a range of illnesses. Exposure to a hot environment, can result in elevated body temperature because the body cannot properly transport heat or because the external heat gain is excessive. Heat stress is defined as the total heat load to which an employee may be subjected as a result of metabolic heat, environmental conditions (such as air temperature, humidity, air movement, and radiation heat), and clothing needs. Heat stress occurs when the body's ability to regulate its internal temperature begins to fail. It is produced both externally by ambient temperature and inside by human metabolism. Excessive heat can produce heat stroke, which can be fatal or result in lasting damage (NIOSH, 2024).

Extremely cold and extremely hot are the two categories into which extreme temperatures fall. Cold temperatures are characterized by a decrease in manual dexterity and an exacerbation of nerve-end dysfunction symptoms. When the body is exposed to cold, its deep core temperature drops, a condition known as cold stress. When exposed

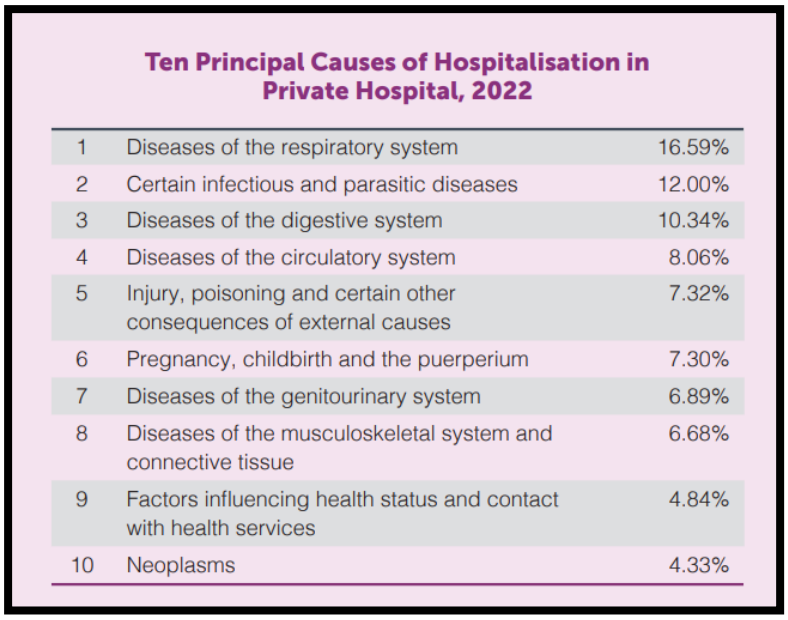
to cold, a worker may exhibit systemic symptoms such as dilated pupils, cardiac fibrillation, shivering, confused consciousness and pain in the extremities (NIOSH, 2024).

The entire load the body must bear is known as heat stress. It is produced both inside by human metabolism and outside by ambient temperature. Heat stroke, a disorder that can be fatal or cause lasting damage, is brought on by excessive heat. Heat exhaustion, heat cramps, and heat-related diseases (such as dehydration, electrolyte imbalance, and loss of physical/mental work capability) are less serious conditions linked to high heat. However, Malaysia experiences only hot weather, and workers on building sites are subjected to extreme heat (NIOSH, 2024).

## 2.4 Work-Related Musculoskeletal Disorders (WMSDs)

### 2.4.1 Definition of WMSDs

Workers in the construction industry are around 50% more likely to develop WMSDs. As a result, the construction industry frequently engages in higher medical expenses and compensation costs for injured workers (Dong et al., 2019). To some extent, construction workers are involved with challenging tasks. Due to the construction and building industries' adaptability, diversity, and dynamic nature (Katode M et al., 2021). Workers in the construction industry are at risk of limitations, injuries, illness, and even death due to the broad scope of their work and the complexity of the projects. Construction is one of the seven jobs with the highest incidence rates. Work-related musculoskeletal diseases (WRMSDs) affect a substantial number of employees, resulting in substantial financial losses. (Katode M et al., 2021). According to 2023 Health Facts by Ministry of Health Malaysia, Diseases of Musculoskeletal System and Connective Tissue included in Ten Principal Causes of Hospitalization in Private Hospital, 2022 as shown in Figure 2.3 below.



**Ten Principal Causes of Hospitalisation in Private Hospital, 2022**

| | | |
|---|---|---|
| 1 | Diseases of the respiratory system | 16.59% |
| 2 | Certain infectious and parasitic diseases | 12.00% |
| 3 | Diseases of the digestive system | 10.34% |
| 4 | Diseases of the circulatory system | 8.06% |
| 5 | Injury, poisoning and certain other consequences of external causes | 7.32% |
| 6 | Pregnancy, childbirth and the puerperium | 7.30% |
| 7 | Diseases of the genitourinary system | 6.89% |
| 8 | Diseases of the musculoskeletal system and connective tissue | 6.68% |
| 9 | Factors influencing health status and contact with health services | 4.84% |
| 10 | Neoplasms | 4.33% |

Figure 2.3 Ten Principal Causes of Hospitalization in Private Hospital

### 2.4.2 Affected Body Parts

Table 2.2
Summarises the Affected Body Parts Against Trades

| AFFECTED BODY /TRADES | Hand /Fingers | Lower back | Foot /Ankles | Knees | Shoulder | Head / Neck | Wrist |
|---|---|---|---|---|---|---|---|
| Masonry / Bricklayer | √ | √ | √ | √ | √ | √ | √ |
| Concreting | | √ | √ | √ | √ | | |
| Roofing | | √ | √ | √ | | √ | |
| Painting / Plastering | √ | | | | √ | | √ |
| Barbender | √ | √ | | | √ | | √ |
| Plumber | | √ | | √ | √ | √ | |
| Electrician | √ | √ | √ | √ | √ | √ | √ |
| General Workers | √ | √ | | | √ | | |

Note. Data compiled from Lop et al., (2019) and Daruis, Deros & Jeyasekaran (2019)

Table 2.2 shows affected body pain go through by the trades. According to Lop et al. (2019), long-term exposure to ERF can cause symptoms, physical indications, and injuries, including musculoskeletal disorders (MSD). Risks in the construction sector vary according on the task at duty. Employers and workers must be aware of ergonomic risk factors to reduce the potential for MSD injuries associated with tasks. In reality, not every worker who is exposed to risk factors will acquire MSDs. For instance, two workers exposed to the same risk factors may react differently due to individual differences in physical fit. Based on the results as well indicate that mixing and carrying

concrete are associated with greater rates of musculoskeletal problems. This might be caused by repeated tasks over time. Manually lifting and mixing heavy materials, as well as putting fresh concrete, posed ergonomic risks due to repetitive movements and difficult postures. The ERF affects the lower and upper back, shoulder, hand, wrist, and knees. Repetitive bodily movements might harm muscles over time.

In addition, Daruis, Deros & Jeyasekaran (2019) in their research also indicate that majority of the trades having lower back pain as shown in the figure 2.4 below. The results of the body pain are based on the Rapid Entire Body Assessment (REBA) to identify, assess and evaluate the entire body segments for Work-related Musculoskeletal Disorders (WMSDs) to entire body segments that include the following body parts: neck, shoulder, upper back, lower back, elbow, hand, thigh, knee, legs, trunk, arms, and wrist. This also agreed by Jeong et al. (2020) in his studies shows that the results of the top three (3) most common complaints about bodily parts or areas of pain or discomfort are identical to those from the preceding section. Shoulders, low back, and wrists/hands were the most common sources of pain or discomfort among responders, whereas hips/thighs got no complaint.

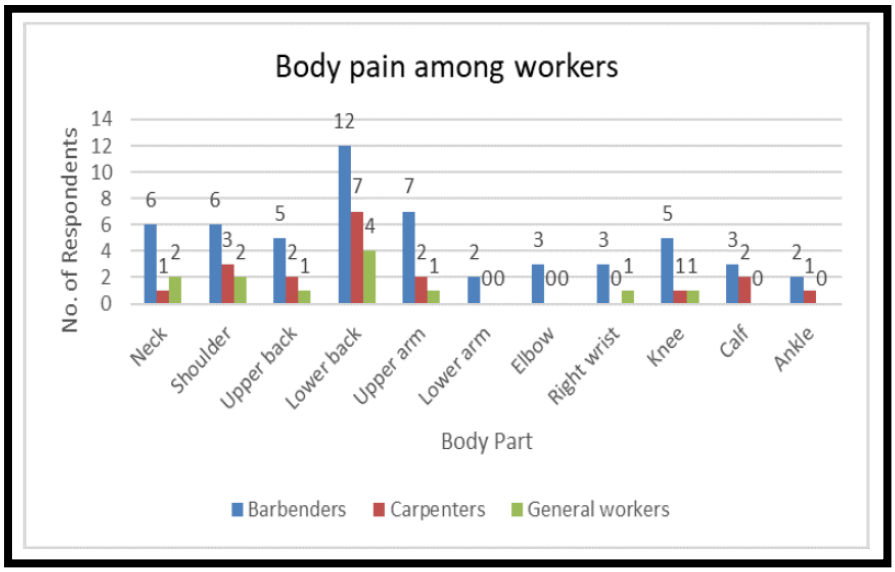



Figure 2.4 Body Pain Among Workers

Note. Data from Daruis, Deros & Jeyasekaran (2019)

As presented in table 2.2, lower back and shoulder pain are the most prevalent among all trades. These are followed by discomfort in the hands or fingers, as well as the knees. Pain in the feet or ankles, head or neck, and wrists are the least commonly

reported. P.S Kothai et al. (2022) noted that, Low back pain (LBP) is one of the severe and common injuries in WMSDs and with the LBP the knee pain, shoulder pain, spine and neck pain is also considerable parts of body where the WMSDs might affect a worker. Nyamboki et al. (2023) also agreed, back and waist pain were the most commonly affected body areas, followed by general body aches, sore muscles, and joint pain. Whilst, Mbada et al. (2022) indicate that workers in the construction industry frequently experience work-related musculoskeletal disorders due to constant exposure to occupational hazards. This group includes masons, carpenters, electricians, plumbers, and others. Also, few numbers of plumber that suffer more from WMSDs affecting the low back area. However, P.kisi and Kayastha (2024) reported that the three most common musculoskeletal injuries and disorders (MSPs) were identified across various construction occupations, such as roofers, drywall installers, plumbers, masonry workers, and labor or helpers.

### 2.4.3 Relationship between Ergonomics Risk and WMSDs

A strong relationship exists between ergonomic risk factors and the development of work-related musculoskeletal disorders (WMSDs) among construction workers. Ergonomic risk factors arise when job demands exceed a worker's physical capabilities, resulting in excessive stress on muscles, tendons, ligaments, joints, and the skeletal system. Common ergonomic hazards in construction include manual material handling, repetitive work activities, forceful exertions, prolonged standing, vibration exposure from machinery, and sustained awkward postures such as bending, kneeling, twisting, and overhead reaching. Over time, continuous exposure to these hazards can cause cumulative trauma to the musculoskeletal system, leading to pain, discomfort, fatigue, and reduced functional capacity.

In the Malaysian construction industry, studies have consistently reported that workers exposed to high ergonomic demands are more susceptible to developing musculoskeletal symptoms, particularly in the lower back, shoulders, neck, knees, and wrists (Abas et al., 2018; Lop et al., 2019). The prevalence and severity of WMSDs tend to increase with the frequency, intensity, and duration of exposure to ergonomic hazards. Besides affecting workers' health and quality of life, WMSDs can also contribute to reduced productivity, increased absenteeism, higher medical costs, and a greater risk of workplace accidents due to physical fatigue and reduced concentration.

Therefore, the implementation of ergonomic risk assessments, proper work methods, mechanical lifting aids, and worker training is essential to minimise ergonomic risks and improve occupational safety and health performance on construction sites.

### 2.4.4 Effect WMSDs to Construction

Ergonomic risk among the trades also brought to the effect in construction industry. The effect are consistent pain to workers, higher health care or compensation expenditures, financial to the project performance, pressure on workers to raise their output and fatigue and strain. All the effect are explained by turn below.

#### *2.4.4.1 Consistent Pain to Workers (Working Hurt)*

On the construction site, ergonomic hazards can cause severe and crippling wounds to joints and muscles. The more the exposure to a single risk factor or a combination of risk factors, the greater the possibility of ergonomic harm or disease, also known as Work Related Musculoskeletal Disorders (WMSD). They can develop into long term and devastating medical difficulties that keep people from working and enjoying life (Francis & Deepan, 2019). Ergonomic risks can cause constant discomfort to workers, who often continue working despite the pain. Recent studies confirm that such risks contribute to work-related musculoskeletal disorders (WMSDs) among construction workers, adversely affecting their long-term health and productivity (Tao et al., 2024; Jeong et al., 2024).

#### *2.4.4.2 Higher Health Care and Compensation Expenditures*

Poor workplace health and safety will result in increased penalties for breaches of workplace safety and health legislation, higher insurance premiums, and higher employment costs. Furthermore, establishing a successful OSH programme and developing OSH teams will result in fewer turnover, decreased absenteeism, and higher productivity, which will boost corporate profit. Ergonomic programmes in safety and health can assist reduce construction accidents and injuries while also increasing productivity and efficiency of labour, product quality, and worker morale. Furthermore, ergonomic compliance in workplace health and safety is required for increased

productivity and efficiency in order to improve the company's reputation (Abdul Aziz et al., 2019).

As a result, the construction sector in Malaysia frequently incurs substantial health, safety, and compensation burdens for injured workers and employers (Awaluddin et al., 2023; Krishnasamy et al., 2025). To some extent construction employees engage in activities that are difficult. Because of the construction and building industry's changeability, variety, and dynamic qualities. The extensive range of the job and the difficulty of the projects in the construction sector expose workers to disabilities, diseases, accidents, and even death. One of the seven jobs with the greatest incidence rate is construction. Work-related musculoskeletal disorders (WRMSDs) are common among many employees, and a large amount of money is spent as a result (Krishnan et al., 2021).

#### *2.4.4.3 Financial Effect on the Project's Performance*

Furthermore, demonstrated that workplace accidents significantly effect on workers' psychological and behavioural well-being. Accidents that occur on a construction site may create a delay in the completion of the project, which is connected to the time factor in project performance. Besides, the accident had an influence on project performance in terms of indirect workplace expenses to the company and workers. This is due to an increasing in expenditures, which has a financial effect on the project's performance. It is further backed by the fact that safe and healthy workplaces are critical since they not only protect employees but also boost productivity. As a result, as the occupational safety and health (OSH) culture grows, workplace accidents can be minimized while also improving efficiency, productivity, and corporate performance. Hence, it is vital to determine the causes and effects of accidents on construction projects, as well as the influence of work accidents as Occupational Safety and Health (OSH) concept on project performance (Abdul Aziz et al., 2020).

Besides, stakeholder involvement is very important in influencing ergonomic risk factor among the workers because it affects the productivity of workers in construction industry and all the highest level should put their awareness to these issues. As ergonomic hazards have a consequence on building products, all involved stakeholders must specialize on the areas that have the foremost impact on construction

ergonomics. Center incorporates hazard identification and chance appraisal, and within the event that conceivable alteration of the plan, and details or specification, and appropriation of elective strategies of labor and organization of the work place (Weale et al., 2022).

#### *2.4.4.4 Pressure on Workers to Raise Their Output*

Other than that, the construction sector is a difficult place to work since its physical operations can result in a variety of ergonomic issues. The industry is distinguished from others by having the greatest worker injury and death rates, making it the highest risk 191 sector in terms of WMSDs. Every construction worker is likely to be temporarily unable to work as a result of relatively significant injuries or health problems sustained while working on a building site at some point (Kadir et al., 2025). This can gradually put pressure on workers to raise their output, which opens the door for shortcuts to be taken instead of following safe work procedures that are also designed prior to the start of work (Sneller et al., 2019).

#### *2.4.4.5 Fatigue and Strain*

Musculoskeletal injuries are a major risk for construction workers of all trades. It is depending on the tasks performed by construction workers, as each of these occupations requires different physical body motions. The physically demanding nature of the industry, awkward and static postures, vibration, harsh outside climate, and other risk factors, have all contribute to strains and sprains as a kind of work-related injury in construction. Construction works undertaken by workers are frequently repetitive and physically demanding. Execution of such tasks in uncomfortable postures can strain their body parts and might result in discomfort, injuries or in severe circumstances permanent incapacity. These injuries are generally caused by poor work posture when doing tasks such as lifting loads (back and knee injuries) and working overhead (neck and shoulder injuries) (Lop et al., 2019).

## 2.5 Ergonomic Risk Management and Improvement Measures

Ergonomic risk management is a proactive approach that seeks to identify and mitigate workplace hazards that may adversely affect workers' musculoskeletal health. In construction environments, ergonomic risk management addresses common hazards such as heavy lifting, repetitive work activities, forceful exertions, awkward body positions, and vibration exposure. The effective implementation of ergonomic control measures can help prevent work-related musculoskeletal disorders, improve employee comfort and performance, and promote a safer and more productive working environment.

### 2.5.1 Mitigation Strategies

Despite ergonomic risk and the effects explained previously**,** there are strategies for elimination or reduction of exposure to hazard and associated risk. These strategies can be considered to be more effective when the workplace of MSD symptom is mild and potentially reversible. The following section outlines methods for preventing or improving ergonomic risks.

#### *2.5.1.1 Safety and Health Program*

Good safety programmes and proper occupational safety and health management systems (OS-HMS) can significantly reduce injuries on construction sites, lower accident-related costs, enhance productivity, and save workers' lives (Wong et. al, 2023; Krishnasamy et. al, 2025) Albarkani & Shafii (2021) observed that staff training is a work activity that can make a very significant contribution to the overall effectiveness and profitability of an organization. They, therefore, provides a systematic approach to training which encases the main elements of training. After the training program, an evaluation is carried out to ascertain the effectiveness of the "program in line with the need'' which had been identified. It is worthy of mention that organization development follows the development of individual who form the organization.

One of the suggested strategies is to incorporate incentive programs into construction projects. Safety incentive programs refer to programs that reward workers for achieving certain goals related to workplace safety (Abas et al., 2020). Some studies

show that safety incentive programs can improve many safety performances at the construction site. Abas et al. (2020) also indicate that, this is an initiative that rewards employees for improving their safety procedures and decreasing the number of reported injuries and incidents. Injury-based reward programmes and behavior-based incentive programmes are the two types of safety incentive programmes. In other words, this is the use of a reward system to implement security programmes such as Behavior-Based Safety (BBS) or Injury-Based Safety (IBS). These programmes can be implemented in both passive and proactive ways, such as proactive safety incentive programmes that reward workers for actions such as making safety recommendations, identifying or correcting hazards, participating in programme health, or serving on the security committee or task force (Abas et al., 2020).

Besides, stakeholder involvement plays a crucial role in influencing ergonomic and occupational risk factors among construction workers, which in turn affects their productivity; thus, all relevant stakeholder groups especially top-level decision-makers should maintain high awareness of these issues (Abas et al., 2022; Muslim, 2023).
In addition, effective management of how construction work is implemented is vital, as poor task organization and work-environment planning can increase ergonomic risk factors for workers (Qin et al., 2024; Karim et al., 2024). Contractors, workers and unions have to cooperate to discover activities that occur inside the boundaries of their working environment. To change their attitudes, ergonomists should include them particular cases of how construction workers can be affected by aggregate injuries. Ergonomists also need to make a forecast of what construction workers will be like within the future if that don't alert of themselves within the current working conditions (Grytnes et al., 2020).

As ergonomic hazards have a consequence on building products, all involved stakeholders must specialize on the areas that have the foremost impact on construction ergonomics. Center incorporates hazard identification and chance appraisal, and within the event that conceivable alteration of the plan, and details or specification, and appropriation of elective strategies of labor and organization of the work place (Tao et al., 2024).

Ergonomics is organizing an occupation to fit the worker so the work is more secure and dynamically viable. Executing ergonomic courses of action can make workers dynamically pleasant and increase benefit. Ergonomic perils and inactive condition to some degree exist in essentially all work system and can be

missed in standard risk examination tries. Various affiliation questionable of the ergonomic danger level in their action or the impact it has on the commerce, have a tremendous open entryway for improvement. For an affiliation to progress its capacity to supervise ergonomic hazard, a successful ergonomic hazard evaluation process is anticipated to decrease hazard to a satisfactory measurement. The point of the examination was to concentrate on recognizing the hazard variables display within the wanders and to set up a few effective restorative measures, ergonomic instruments and procedures to decrease, take out the hazard variables, and make consideration to ergonomics interior building site and shield workers from MSDs (Francis & Deepan, 2019).

The awareness from stakeholders particularly in construction industry and workers is needed and musculoskeletal disorders (MSDs) shall be taken as an important issue with clearly understandable.

#### *2.5.1.2 Personal Protective Equipment (PPE)*

Personal Protective Equipment (PPE) is equipment worn to minimize exposure to serious workplace injuries and illnesses. The PPE is also worn to reduce exposure to ergonomics-related risk factors. These injuries and illness may come from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Example of PPE equipment are such as gloves, safety glass, shoes, earplugs, hard hats, respirators, vests and full body suits. The example of the uses of PPE in workplace are such using padding to reduce direct contact with hard, sharp, or vibrating surfaces and wearing good fitting thermal gloves to help with cold conditions while maintaining the ability to grasp items easily (Malta et al., 2024; Khoshakhlagh et al., 2024).

#### *2.5.1.3 Engineering Controls*

Engineering controls are considered the preferred method for controlling ergonomic hazards because they physically modify the workplace, tools, or work processes to reduce workers' exposure to risk factors such as excessive force, awkward postures, repetitive motions, and vibration. OSHA identifies engineering controls as the most effective approach for preventing musculoskeletal disorders (MSDs) because they

eliminate or reduce hazards at their source (Antwi-Afari et al., 2023; Vijayakumar & Choi, 2022).

Examples of engineering controls in construction include:

Mechanical lifting devices (e.g., cranes, hoists, vacuum lifters, and material lifts) to reduce manual material handling and force exertion. OSHA specifically recommends lifting and repositioning devices to limit worker exposure to heavy-load handling.

Adjustable scaffolding and elevated work platforms that allow workers to maintain neutral postures and minimize bending, kneeling, and overhead reaching during construction tasks. Properly designed scaffolding systems can improve access to work areas and reduce ergonomic strain.

Ergonomically designed hand tools, such as low-vibration power tools, extended-handle tools, and powered rebar-tying devices, which reduce repetitive movements, force requirements, and awkward wrist positions. NIOSH found that powered rebar-tying tools can significantly reduce stooping and repetitive hand motions associated with traditional manual rebar tying.

Workstation and material-handling redesign, including positioning materials at waist height, shortening reaching distances, and using conveyors or carts to move materials instead of manual carrying. OSHA's technical guidance recommends designing workstations to minimize lifting distances, excessive reaches, and awkward trunk flexion.

Prefabrication and modular construction techniques, which reduce the amount of manual assembly, lifting, and repetitive tasks performed on-site, thereby lowering ergonomic exposure among construction workers. NIOSH notes that modifying work processes to reduce physically demanding tasks is a practical and cost-effective ergonomic intervention.

Research indicates that engineering controls not only reduce injury risk but can also improve productivity, work efficiency, and overall worker comfort. OSHA reports that organizations implementing ergonomic engineering solutions have experienced lower injury rates, reduced compensation costs, and improved operational performance

#### *2.5.1.4 Improved Workstation and Site layout*

Improved workstation and site layout can mitigate ergonomic risks on construction sites by minimizing awkward postures, excessive reaching, and manual material handling. Strategic placement of materials and tools, provision of adjustable work platforms, and effective construction site layout planning enable workers to maintain neutral postures and reduce musculoskeletal loading during construction activities (Palikhe et al., 2022; El-Rayes et al., 2023).

Furthermore, research on ergonomic workstation improvement frameworks emphasizes that workstation layout, work height, reach distance, and accessibility are critical factors influencing worker posture and physical workload. Optimizing these factors helps reduce musculoskeletal strain and supports safer task performance.

#### *2.5.1.5 Health Monitoring and Continues Improvement*

Health monitoring is an effective ergonomic risk mitigation strategy in construction because it facilitates the early detection of musculoskeletal symptoms, monitors worker exposure to physical risk factors, and supports timely intervention before injuries become severe. Regular health surveillance, ergonomic assessments, and the use of wearable monitoring technologies can significantly improve the prevention and management of work-related musculoskeletal disorders among construction workers (Zhao et al., 2021; Antwi-Afari et al., 2023; Chen et al., 2024).

## 2.6 Role of Technology in Ergonomics

Intelligent systems have garnered broad attention in various industries in recent years, owing to the rapid development of the fourth industrial revolution and new platforms of information technologies, and have the potential to increase the efficiency of the construction industry. The Fourth Industrial Revolution is defined by Industry 4.0, a new level in the organization and management of the whole value chain of a product's and manufacturing system's life cycle. Construction 4.0 is the equivalent exploration of new technologies in the Architecture, Engineering, Construction and Operations (AECO) industry (Schönbeck, Löfsjögård & Ansell, 2020).

Industry 4.0 includes systems in which sensors, machines and robots communicate with each other over the internet, simultaneously collecting massive amounts of real-time information and storing them using cloud-based technology (Serap Tepe,2021). Various levels and components of the Construction 4.0 framework can be seen in Figure 2.6 (Anil Sawhney et al., 2020).

Additionally, the Malaysian construction industry is currently working on the application of IoT that is connected to building information modelling (BIM), augmented reality, cloud computing, and big data analytics. However, the implementation is still very much in its early stages, and needs improvement as well as requires more expertise in managing IoT implementation in Malaysia (Ibrahim, Esa & A. Rahman, 2020). Industry 4.0 once implemented successfully in Malaysia may reduce workforce in technology upgraded industry (Raj et al., 2020).

The Significance of the Internet of Things (IoT) can be seen in almost every industry, including construction, where internet connection becomes the core medium between human and technology (Ibrahim, Esa & A. Rahman, 2020). Figure 2.5 presents the many sensors (embedded on devices/equipment/tags) to monitor construction sites activities. The hardware devices/equipment can bring embedded more than one type of sensor (e.g., smartphones, smartwatches, cranes, etc.).

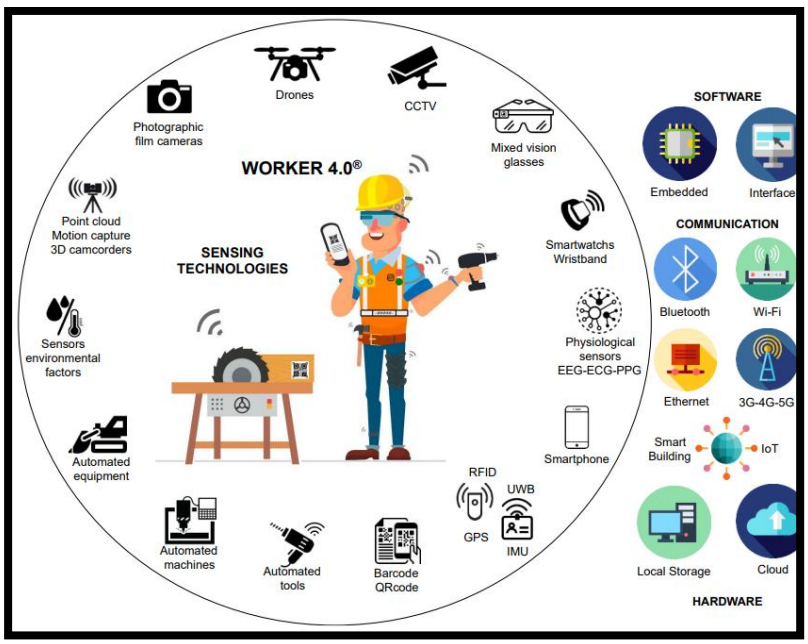


Figure 2.5 Construction Sites Activity using Construction 4.0

### 2.6.1 Digital Tools

Digital tools have transformed construction site management by enhancing safety, productivity, communication, and quality control. Technologies such as Building Information Modeling (BIM), wearable sensors, drones, artificial intelligence, and Internet of Things (IoT) devices enable real-time monitoring and data-driven decision-making. These tools support hazard identification, ergonomic risk assessment, project coordination, and quality management, ultimately improving overall project performance and worker safety (Darko et al., 2022; Antwi-Afari et al., 2023; Wang et al., 2024).

### 2.6.2 Automation

Automation is increasingly being adopted in the construction industry to improve productivity, safety, quality, and efficiency. It involves the use of technologies such as robotics, autonomous equipment, drones, artificial intelligence (AI), machine learning, and automated monitoring systems to perform tasks with minimal human intervention. Automation helps address major industry challenges, including labor shortages, safety risks, schedule delays, and cost overruns.

Automation has become an important driver of innovation in the construction industry by improving productivity, safety, quality, and worker well-being. Technologies such as robotics, autonomous equipment, drones, artificial intelligence, and wearable exoskeletons reduce manual labor requirements, minimize worker exposure to hazardous conditions, and enhance construction efficiency. Furthermore, automation can mitigate ergonomic risks by reducing repetitive motions, manual material handling, and awkward postures, thereby lowering the incidence of work-related musculoskeletal disorders among construction workers (Antwi-Afari et al., 2023; Zhou et al., 2023; Kim et al., 2024).

### 2.6.3 Wearable Tech

Wearable technologies are increasingly used in construction to improve worker safety, health monitoring, productivity, and ergonomic risk management. Wearables are electronic devices worn on the body, such as smart helmets, smartwatches, sensor-

equipped safety vests, exoskeletons, and wearable motion sensors. These devices collect real-time data on workers' physiological conditions, movements, and environmental exposures, enabling proactive safety and health management.

Wearable technologies play an important role in modern construction sites by enhancing worker safety, health monitoring, productivity, and ergonomic risk management. Devices such as smart helmets, wearable sensors, smartwatches, and exoskeletons enable real-time monitoring of worker posture, physiological conditions, and environmental exposures. These technologies facilitate early detection of ergonomic hazards, fatigue, and safety risks, allowing timely interventions to prevent injuries and improve overall site performance (Zhao et al., 2021; Antwi-Afari et al., 2023; Wang et al., 2024).

Wearable technologies enable continuous monitoring of worker posture, physiological responses, and environmental conditions, thereby improving safety management and reducing ergonomic risks on construction sites (Zhao et al., 2021; Antwi-Afari et al., 2023; Wang et al., 2024).

### 2.6.4 Monitoring System

Monitoring plays a critical role in construction site management by ensuring worker safety, improving productivity, maintaining quality standards, and facilitating informed decision-making. Through continuous observation and assessment of site activities, monitoring helps identify potential hazards, track project progress, evaluate worker performance, and ensure compliance with safety and regulatory requirements

Monitoring is a fundamental component of construction site management because it supports safety, health, productivity, quality control, and regulatory compliance. Through the use of digital technologies, wearable sensors, computer vision systems, and real-time data analytics, construction organizations can identify hazards, assess worker health and ergonomic risks, monitor project progress, and improve decision-making. Consequently, effective monitoring contributes to safer working environments, enhanced project performance, and reduced operational risks (Antwi-Afari et al., 2023; Wang et al., 2024; Chen et al., 2024).

## 2.7 Critical Review and Research Gap

The construction industry is recognized as one of the most physically demanding sectors due to its reliance on manual labor, repetitive activities, awkward postures, forceful exertions, and material handling tasks. Workers from different trades, such as carpenters, bricklayers, bar benders, electricians, plasterers, and scaffolders, are exposed to varying ergonomic risk factors depending on the nature of their work. These exposures contribute significantly to work-related musculoskeletal disorders (WMSDs), particularly affecting the lower back, shoulders, neck, and upper limbs (Antwi-Afari, Maxwell Fordjour et al., 2023).

While numerous studies have identified ergonomic hazards in construction, most focus on general construction activities rather than trade-specific ergonomic exposures. Since each trade performs unique tasks and utilizes different tools and work methods, ergonomic risks can vary substantially across occupations.

Various ergonomic assessment methods have been used to evaluate construction workers' exposure to musculoskeletal risk factors. Common techniques include:

- Rapid Entire Body Assessment (REBA)
- Rapid Upper Limb Assessment (RULA)
- Ovako Working Posture Analysis System (OWAS)
- Nordic Musculoskeletal Questionnaire (NMQ)

These tools have been widely applied because they are relatively simple and cost-effective. However, many assessment approaches rely heavily on observational methods and snapshots of work activities, which may not adequately capture the dynamic and continuously changing nature of construction work (Vijayakumar & Choi, 2022).

Furthermore, existing assessment studies often focus on individual tasks rather than providing a comprehensive understanding of ergonomic risks across multiple construction trades.

Researchers have proposed various interventions to reduce ergonomic risks in construction, including:

- Engineering controls (mechanical lifting aids, ergonomic tools, adjustable platforms)
- Administrative controls (job rotation, work-rest schedules, training)
- Health monitoring programs
- Wearable technologies
- Automation and robotics

Although these interventions have shown potential in reducing ergonomic exposures, their implementation within the Malaysian construction industry remains limited. Most studies evaluate individual interventions rather than developing a structured framework that integrates risk factors, assessment methods, and mitigation measures into a systematic approach.

The Malaysian construction industry continues to rely heavily on manual labor, particularly among skilled trades and foreign workers. Several local studies have reported a high prevalence of musculoskeletal symptoms among construction workers due to manual material handling, prolonged standing, repetitive tasks, and awkward working postures. However, research on ergonomic risks in Malaysia remains fragmented. Most local studies focus on specific projects, individual trades, or isolated ergonomic issues. There is limited empirical evidence comparing ergonomic risks across multiple construction trades and identifying the most significant contributors to WMSDs within the Malaysian context.

Existing studies predominantly focus on identifying ergonomic hazards or evaluating specific assessment tools. There is a lack of research aimed at developing a comprehensive ergonomic risk framework that systematically links:

- Construction trades
- Ergonomic risk factors
- Risk assessment techniques
- Risk severity levels
- Appropriate mitigation measures

A framework can provide industry practitioners, safety officers, and project managers with a structured approach for identifying, assessing, and controlling ergonomic risks across different construction trades.

Although numerous studies have investigated ergonomic hazards and work-related musculoskeletal disorders in the construction industry, most research has focused on general construction activities rather than specific construction trades. Furthermore, ergonomic studies in Malaysia remain limited and fragmented, with little emphasis on developing a comprehensive framework that integrates ergonomic risk factors, assessment methods, and mitigation strategies. Consequently, there is a need to develop a trade-specific ergonomic risk framework for Malaysian construction sites to support systematic risk identification, assessment, and control, thereby improving worker health, safety, and productivity

## 2.8 Conceptual Framework of This Study

Figure 2.6, shows the conceptual framework in this research. Abas et al (2020) stated that Major construction projects in Malaysia are exposed to dangerous conditions which can cause accidents and consequently affect the safety performance of the construction projects. The causes of accidents in construction industry are related to unique nature of the industry, human behavior, improper site conditions, unsafe work method, equipment and procedures which affected from poor safety management. These causes could result in accidents which further cause disruption of work and decrease the work rate. Kumar Singh et al. (2024) explained that building workers are exposed to excessive construction site dangers that can result in injuries or even death. They face different kinds of safety and health hazards whilst working in their work sites every day.

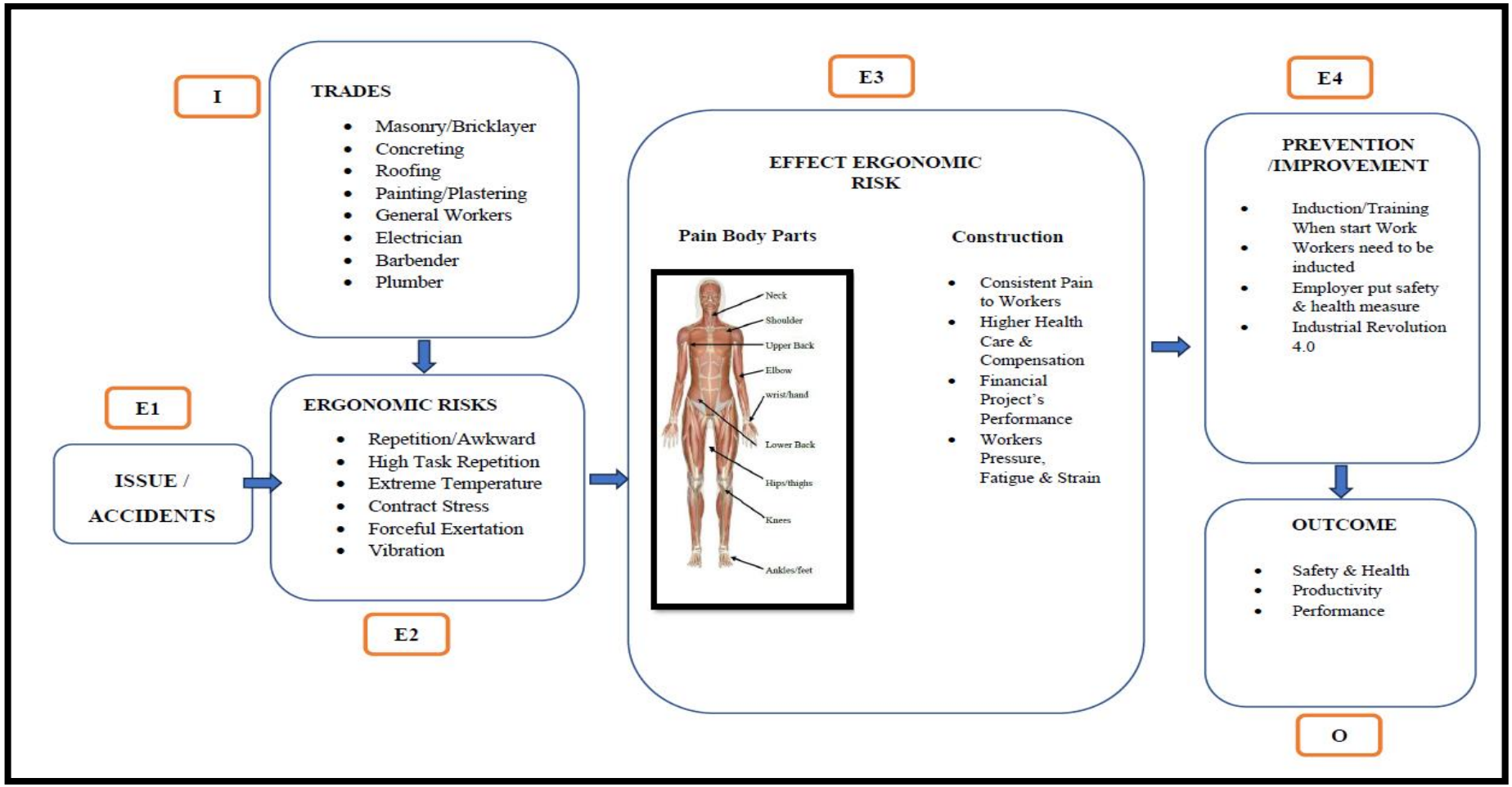



Figure 2.6 Conceptual Framework Ergonomic Risk in Construction

In addition, Construction works typically require the adopting of awkward postures, lifting of heavy materials, manual handling of heavy and irregular-sized loads, frequent bending, bending and twisting of the body, working above the shoulder height, working below the knee level, staying in one position for a long period, climbing and descending, and pushing and pulling of loads. These are all done under difficult circumstances. Because of work types involved, WMSDs are one of the leading causes of occupational injuries in the construction industry (Anagha & Xavier, 2020). From ergonomics perspective, manual material transfer is a high-risk activity that could cause spinal injuries. From physiology aspect, manual material transfer requires high amount of energy and strength. Hence, all activities, if carried out incorrectly, could cause inflammation at the nerves and muscles. MMH activities that involve high physical demands, continuous bending, crouching and hip twisting could disrupt the musculoskeletal system (Rajendran et al.2021).

Work-related musculoskeletal injuries and disorders (WMSDs) are among the most frequently reported causes of lost or restricted work time in the construction industry. Overexertion, sprains, strains, pulls, and/or tears are all an unfortunate regular occurrence on many constructions job sites (Sneller , Ahn & Choi ,2019). According to Hilmi and Abdul Hamid (2023) ergonomic hazards can cause consistent pain to workers, who often choose to work through that pain. According to OSHA, “working hurt” is among the largest problems facing construction workers today, as working hurt can not only lower productivity, but can cause lifelong pain and disability.

The most significant risk factor for workers in the construction field is their posture when doing work activities, as well as their strength and repetition of motions. One of the most essential aspects of achieving occupational safety and health goals through creating a safety and health programme is worker compliance. Many ergonomic tools are available in identifying complaints experienced by the workers. Based on the complaints and studies, many researchers used the ergonomic tools to design the standard framework for the application at different industries depending on the nature of work (Nelfiyanti & Nik Mohamed, 2019).

One of the suggested strategies is to incorporate incentive programs into construction projects. Safety incentive programs refer to programs that reward workers for achieving certain goals related to workplace safety. Injury-based reward programmes and behavior-based incentive programmes are the two types of safety

incentive programmes. In other words, this is the use of a reward system to implement security programmes such as Behavior-Based Safety (BBS) or Injury-Based Safety (IBS). These programmes can be implemented in both passive and proactive ways, such as proactive safety incentive programmes that reward workers for actions such as making safety recommendations, identifying or correcting hazards, participating in programme health, or serving on the security committee or task force (Abas et al., 2020).

OHS is a multidisciplinary field that takes proactive measures against work accidents and occupational diseases, informs employees, organizes training, conducts risk assessments and carries out activities to regulate the working life to the extent required by labour laws. OHS, like all other fields of study, is affected by developments in technology, and the innovations brought by Industry 4.0 have the opportunity to be applied to OHS. Therefore, it will probably be necessary to interpret OHS from a new perspective. Thanks to the integration of the basic building blocks of the OHS 4.0 digital transformation process into the field of occupational health and safety, it is interpreted as a new trend aimed at proactively protecting the health and safety of employees by maximizing human and machine compliance with safety procedures (Tepe, 2021).

As a last perspective, several elements have been identified that can impact the safety performance of the construction site. Implementing these safety elements has a variety of benefits, including reducing the frequency of accidents on the construction site, increasing productivity, completing the project on time, lowering compensation costs, and improving employee morale. Good project-level safety performance can lead to improved safety performance in the construction sector. Additional, Construction 4.0 also brings a lot of benefit.

The construction sector is widely regarded as one of the most hazardous and injury-prone industries worldwide. It frequently involves the use of machinery and power tools, working on elevated scaffolding, and performing manual handling tasks. Poor working conditions can lead to injuries and occupational health issues, which in turn affect both the national economy and workers' well-being. Work-related musculoskeletal disorders are typical occupational risks associated with exposure to such unsafe environments. Although this study provides a decent understanding of the ergonomic risk in construction industry there are some limitations to be addressed in the development of conceptual framework. Table 2.3 show the challenge of development of framework in construction site.

Table 2.3
Challenge of Development of Framework in Construction Site.

| Challenges | Description | Sources |
|---|---|---|
| Limited Awareness & Cultural Resistance | Limited understanding; resistance to change | Ali et al. (2025) and Ficore Safety (2025) |
| Funding | Training, tools, and tech adoption constrained by budgets | Gislason (2025) and Qin et al. (2024) |
| Technical Validity | Manual vs. automated tool limitations; lack of comprehensive assessment integration | Daruis et al. (2019) and Qin et al. (2024) |
| Organizational Infrastructure | Weak enforcement, poor training systems, coordination issues in fragmented work arrangements | Abdul Halim et al. (2022) and Malaysian Standard 1722:2011 (n.d) |
| Skilled Workforce | Shortage of ergonomics-trained personnel | Roseli et al. (2024) |
| Adoption & Productivity | Resistance to new tools; perceived cost/slowdown | Yap et al. (2022) and Arabshahi et al. (2021) |

According to table 2.3, there is minimal awareness and cultural opposition to the development of an ergonomic risk framework. Ali et al. (2025) explained that, various firms, underestimate the relevance of ergonomics, considering that injuries are unavoidable rather than preventable. Workers and managers frequently oppose implementing new practices, viewing ergonomics as disruptive or unnecessary adjustments (Ficore Safety, 2025). Additionally, training, tools and technology adoption constrained by budget. Gislason (2025) and Qin et al. (2024) indicate that, acquiring ergonomic equipment, training programs, and innovative technology might cost more than the budget allows, making investment difficult to justify. Furthermore, real-time monitoring technologies (e.g., wearables, AI systems) are expensive and frequently difficult to sustain in low-margin projects.

Other than that, manual and automated tools limitation and lack of comprehensive assessment integration. Using manual observation tools (such as REBA) is time-consuming, labour-intensive, and may lack accuracy. Furthermore, automated solutions (wearables, computer vision) frequently focus on a single dimension (e.g., posture) without completely integrating environmental, workload, or psychological aspects, limiting comprehensive danger identification. Then, the lack of standardization

makes it difficult to incorporate several methodologies into a single evaluation framework.

Furthermore, Abdul Halim et al. (2022) and Malaysian Standard 1722:2011 (n.d) state that Ergonomic and OHS regulations (e.g., MS 1722:2011) are inconsistently enforced; many organizations lack defined responsibility and training procedures, and high turnover, subcontracting sections, and language issues in multicultural groups of workers make communication and implementation difficult. Next is resistance to new tool sand perceived cost or slowdown. Based on Yap et al. (2022) and Arabshahi et al. (2021), there is a significant shortage of experienced, ergonomically skilled people, especially in installing technology like exoskeletons, wearable sensors, REBA, or predictive models.

Lastly, Adoption of innovative technologies (e.g., ergonomic wearables, posture sensors, AI models) is hampered by expensive costs and concerns about reduced productivity during training. Furthermore, bigger studies reveal a reluctance to adopt ergonomically designed instruments unless they equal the speed and efficiency of conventional tools (Yap et al. ,2022; Arabshahi et al. ,2021)

## 2.9 Summary

This chapter discussed ergonomic risk in the construction industry and site, its impact, and how to improve ergonomic risk in the construction industry. Additionally, there is a barrier in building the ergonomic framework as shown in the table previously. The following chapter, Chapter 3, provides the research methodology and sequence of this research.

# CHAPTER 3
# RESEARCH METHODOLOGY

## 3.1 Introduction

A brief overview of the research methodology is provided in Chapter 1, while Chapter 2 reviews relevant ergonomic risks associated with various trades in the construction industry. This essential information forms the conceptual framework of the study, which encompasses four key areas: (1) Issues and accidents on construction sites, (2) Ergonomic risks, (3) Effects of ergonomic risks, and (4) Improvements or preventive measures and (5) their outcomes in mitigating ergonomic risks within the construction sector. Building upon this vital, the current chapter offers a detailed explanation and discussion of the specific methodologies and methods employed to achieve the research aims and objectives.

## 3.2 Research Design

Research is often likened to a "voyage of discovery," as it combines experience and reasoning in a systematic pursuit of knowledge. It involves thoroughly examining and analysing the contextual factors surrounding a problem to uncover potential solutions. (Fellow and Liu, 2008). Mahmud (2008) defines research as an organized, systematic, data-driven, critical, objective, and scientific inquiry into a specific issue, conducted with the aim of finding answers or gaining clarity. Supporting this perspective, Saunders et al. (2009) emphasize that research is a deliberate and methodical process undertaken by individuals to discover new insights and expand their understanding.

The study utilized a descriptive and cross-sectional design. Descriptive design aims to collect measurable data that may be utilized to statistically evaluate a certain participant or issue (Benard, 2012). It’s commonly used to describe an issue and its features. It is a significant design because participants are observed in their natural and unaltered surroundings (Grime et al., 2002). On the other hand, the researcher utilized a cross-sectional design to reach conclusions about the population of interest. At this study, the researcher used it to evaluate the ergonomic risk factors at construction sites

as well as their effects. The research strategy thus focused on developing an awareness of the ergonomic risk factors in the construction sector and their relationship to Musculoskeletal Disorders.

## 3.3 Study Population and Sample

The target population was construction workers from National Construction Authority registered building construction sites carrying out residential building in Selangor area (Figure 3.1) at the time of data collection (2024). The population comprised of skilled and unskilled labors. Only four (4) numbers on going residential project chosen for the sample due to the limited timeline of the study. Malaysia's housing market has traditionally been recognised as a major contributor to the national economy (Hassanudin Mohd, 2023). In addition, statistics published by the Department of Statistics Malaysia (DOSM) show that residential building and civil engineering projects continue to be significant drivers of growth within the construction sector, with civil engineering representing over 40% of the total construction work value in 2023. As Selangor consistently contributes the largest share of construction activities nationwide, particularly in the residential and civil engineering subsectors, it was considered a suitable location for conducting this study.

Respondent for the research are selected trades among the workers that have basic knowledge about the practical of the ergonomics on site. The selected trades are bricklayer or masonry, concreting, roofing, painting or plastering. Normally, there are 100 trades on site. Thus, Population of the respondents is considered as 100 trades person per site.

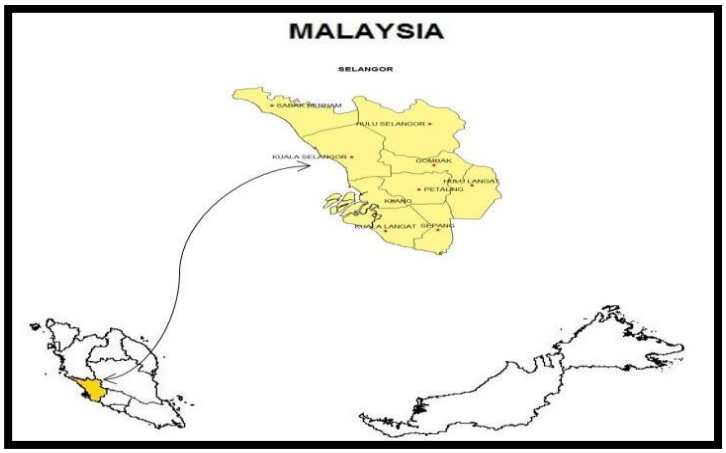


Figure 3.1 Selangor area

Based on the table by Krejcie and Morgan (1970) in Figure 3.2, population of workers for each project 100 numbers and sample would be 80 numbers for each project. This figure had been chosen due to the average numbers of overall trades at site is 100 numbers.

| *N* | *S* | *N* | *S* | *N* | *S* |
|---|---|---|---|---|---|
| 10 | 10 | 220 | 140 | 1200 | 291 |
| 15 | 14 | 230 | 144 | 1300 | 297 |
| 20 | 19 | 240 | 148 | 1400 | 302 |
| 25 | 24 | 250 | 152 | 1500 | 306 |
| 30 | 28 | 260 | 155 | 1600 | 310 |
| 35 | 32 | 270 | 159 | 1700 | 313 |
| 40 | 36 | 280 | 162 | 1800 | 317 |
| 45 | 40 | 290 | 165 | 1900 | 320 |
| 50 | 44 | 300 | 169 | 2000 | 322 |
| 55 | 48 | 320 | 175 | 2200 | 327 |
| 60 | 52 | 340 | 181 | 2400 | 331 |
| 65 | 56 | 360 | 186 | 2600 | 335 |
| 70 | 59 | 380 | 191 | 2800 | 338 |
| 75 | 63 | 400 | 196 | 3000 | 341 |
| 80 | 66 | 420 | 201 | 3500 | 346 |
| 85 | 70 | 440 | 205 | 4000 | 351 |
| 90 | 73 | 460 | 210 | 4500 | 354 |
| 95 | 76 | 480 | 214 | 5000 | 357 |
| 100 | 80 | 500 | 217 | 6000 | 361 |
| 110 | 86 | 550 | 226 | 7000 | 364 |
| 120 | 92 | 600 | 234 | 8000 | 367 |
| 130 | 97 | 650 | 242 | 9000 | 368 |
| 140 | 103 | 700 | 248 | 10000 | 370 |
| 150 | 108 | 750 | 254 | 15000 | 375 |
| 160 | 113 | 800 | 260 | 20000 | 377 |
| 170 | 118 | 850 | 265 | 30000 | 379 |
| 180 | 123 | 900 | 269 | 40000 | 380 |
| 190 | 127 | 950 | 274 | 50000 | 381 |
| 200 | 132 | 1000 | 278 | 75000 | 382 |
| 210 | 136 | 1100 | 285 | 1000000 | 384 |

Note.—*N* is population size. *S* is sample size.

Figure 3.2 Krejcie and Morgan (1970) Table

## 3.4 Data Collection Technique Selected

Figure 3.3 depicts the flow of data collection methods and phases followed to achieve the research aim and objectives. The data collection process was carried out in a structured procedure, consisting of: literature reviews, Preliminary Study (exploratory interview), a questionnaire survey, and validation through an expert panel for the research framework. The four phases of data collection are discussed sequentially in the following sections.

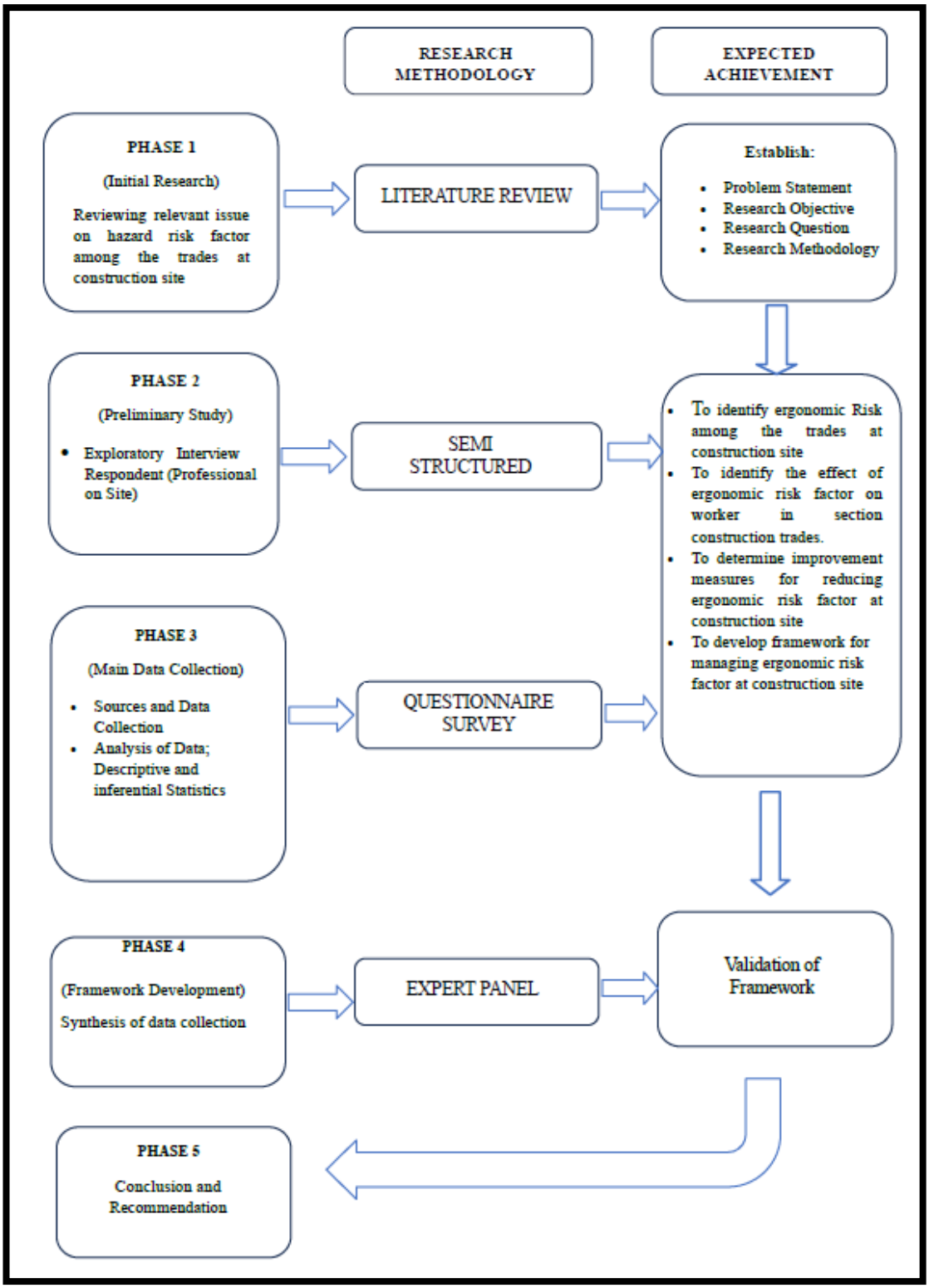



Figure 3.3 Flow of Data Collection Methods

### 3.4.1 Phase 1: Literature Review – Development of Conceptual Framework

The first phase of the research begins with a literature review, which is an essential component of any research project. The review often continues throughout the duration of the study. Hart (1998) defines the literature review as the process of selecting available documents (both published and unpublished) related to the topic. These documents contain information, ideas, data, and evidence, all presented from a specific perspective to meet particular objectives or express certain views on the nature of the topic and how it should be investigated. The effective evaluation of these documents is crucial in relation to the proposed research.

The literature review encompasses a wide range of secondary sources, including books, journal articles, seminar and conference proceedings, reports, and theses and dissertations (Piaw, 2012). It plays a key role in assessing prior research, helping to gather valuable information such as theories, research designs, instruments, procedures, data collection methods, and findings. This ensures that the research is conducted from a scientific perspective and contributes to the broader body of knowledge.

According to Hart (2005) and Naoum (1998), the literature review is a vital aspect of research projects, sometimes accounting for up to 50% of the overall study. For this research, the literature review included a wide array of primary sources, such as academic journals, conference proceedings, reports, books, unpublished theses from local and international universities, and government publications.

The literature review provides information on relevant issues of ergonomic risk in construction, such as effect of ergonomic risk and improvement in ergonomic risk with a focus on studies conducted within the construction sector. Specifically, various existing information are extracted to develop a conceptual framework for Ergonomic Risk Among the Trades in Construction Site. Following the literature review and the development of the conceptual framework for in construction, an initial Preliminary Study was conducted.

### 3.4.2 Phase 2: Preliminary Study

The second phase is the Preliminary Study is an exploratory interview. The purpose of this phase was to assess the existing situation of Trades regarding to Ergonomic Risk in Construction Sites.

#### *3.4.2.1 Exploratory interviews*

A qualitative approach utilising semi structured face-to-face interviews were conducted to explore the issues of ergonomic risk in construction sites. The first part of the question was designed to capture the background of the respondents including their current position and organisation. The second part of the questionnaire seek to gather information of respondents understanding in ergonomic risk. Meanwhile in the third part the respondents were asked on their understanding of IR 4.0 in construction industry.

For the purpose of the exploratory semi-structured interview, ten (10) respondents were identified from four (4) ongoing projects within the construction industry. These potential respondents included a Safety Health Officer, Site Supervisor, Architect, Quantity Surveyor, and Engineer.

### 3.4.3 Phase 3: Questionnaire Survey

A thorough statistical analysis of the information gathered from the questionnaire survey is presented in this phase. The purpose of this study is to provide a framework of ergonomic risk factors for the trades at Malaysian building sites, as stated in chapter 1. The questionnaires were created to capture the four study objectives based on the purpose and information gathered from the literature and preliminary investigation.

Figure 3.4 shows the process involved in designing, piloting, and distributing the questionnaire. The development of the questionnaire was informed by a review of relevant literature and insights obtained from the Preliminary Study, which included exploratory interviews and document analysis. Additionally, the questionnaire items were adopted and adapted from existing literature. Modifications were made to tailor the instrument to effectively address the research questions and objectives.

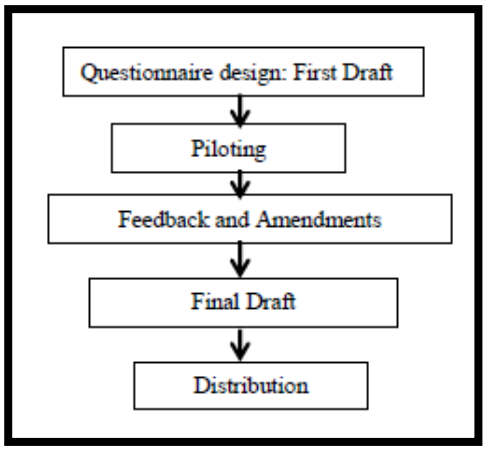


Figure 3.4 Process Designing Questionnaire

### *3.4.3.1 Questionnaire Design*

The questionnaire was structured into three sections: The first section focuses on collecting general information about the respondents, such as their job designation, industry experience, academic qualifications, type of organization, and current project involvement. This section aims to gather demographic data on the survey participants.

**Section A**: In this part, respondents were asked to provide their experience and background in the construction industry.

**Section B**: In this section, respondents were asked to provide their perception of ergonomic risk and safety arrangement.

**Section C**: The aim of this section is to determine the effect of ergonomic risk at construction site. Hence, respondents were required to indicate their perception on the rate of the performance of public projects in term of cost, quality and time.

Sample of the questionnaire survey questions is attached in *Appendix 2.*

### *3.4.3.2 Scale of Measurement*

There are two types of measurement approaches: indexes and scaling. As noted by Sarantakos (1997), indexes are a fundamental component of surveys and questionnaires. They are used to accurately describe and measure broad concepts by incorporating several specific and representative elements of the concept. An index combines multiple items, with their values summed to produce a single numerical score. Scaling, in contrast, is a method commonly used by social scientists for measuring attitudes. Scales comprise a series of statements or questions along with a set of response options that correspond to a particular score.

Response scales are generally divided into two main categories: rating scales and ranking scales (Cavana et al., 2001). Rating scales consist of multiple response options and are used to capture reactions or opinions regarding a specific object, event, or person. In contrast, ranking scales involve making comparisons between or among objects, events, or individuals, and are used to identify preferences and establish a rank order among them.

There are twelve types of rating scales, including: dichotomous scale, category scale, Likert scale, numerical scale, semantic differential scale, itemised rating scale, fixed or constant sum rating scale, Stapel scale, graphic rating scale, consensus scale, Thurstone scale, and multidimensional scale.

The dichotomous scale is designed to elicit a simple "yes" or "no" response, while the category scale uses multiple items to prompt a single response. Both of these scales apply nominal measurement. In contrast, the Likert scale, semantic differential scale, numerical scale, Stapel scale, graphic rating scale, and itemised rating scale are based on interval measurement. The constant sum rating scale aligns more closely with ordinal measurement. For ranking scales, three main types are commonly used: paired comparison, forced choice, and comparative scaling—all of which are ordinal in nature.

For the purpose of this research, a rating scale based on the Likert scale was adopted, as it is one of the most commonly used tools for measuring attitudes (Jamieson, 2004; Narli, 2010), preferences, and opinions (Leung, 2011). The Likert scale is valued for its three fundamental properties: reliability, validity, and sensitivity (Cummin & Gullone, 2000). In addition, it is widely employed in social, psychological, and human factors research (Parker, McDaniel, & Crumpton-Young, 2002).

Although Jamieson (2004) and Cohen et al. (2007) argue that the Likert scale is ordinal in nature—suggesting that data collected should be analyzed using modal scores and non-parametric methods—Cavana et al. (2001) and Leung (2011) contend that it can be treated as an interval scale. Leung (2011) further noted that studies treating Likert scales as continuous outnumber those treating them as ordinal-discrete by a ratio of 2.5 to 1. Similarly, Parker et al. (2002) recommended the use of parametric techniques with Likert scale data, reasoning that even if individual items are not strictly interval in nature, the summed scores may approximate interval-level measurement, making them relatively robust to violations at the item level. This view is supported by Kemp and Grace (2010), who pointed out that responses are effectively treated as interval data when used as a summated rating scale. Rattray and Jones (2007) also affirmed that it is acceptable to treat scores from this type of response format as interval data, allowing for the application of standard parametric tests. Therefore, in this research, the data will be analyzed using summed scores to allow the results to be treated as interval-level measurements.

In addition, Cummin and Gullone (2000) argued that labeling every response category (e.g., 1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree) is unnecessary, as it may detract from the interval nature of the scale and complicate the use of an expanded choice format. They recommended using an end-defined format (e.g., Strongly Agree 1 2 3 4 5 Strongly Disagree), which they found more suitable. Similarly, Saunders et al. (2009) referred to this format as an anchoring rating scale. And this research adopt 1 to 5 likert scale.

#### *3.4.3.3 Piloting the Questionnaire*

Piloting the questionnaire involves testing it on a small group of respondents to identify and address any potential issues. The main objective of the pilot test is to refine the questionnaire to ensure that respondents can answer the questions easily and that data can be recorded accurately (Saunders et al., 2009). According to Malhotra (2006), a questionnaire should not be used in the main study without thorough pretesting. Oppenheim (1992) stresses that every aspect of the questionnaire should be tested—this includes the content, wording, question order, format, layout, and even the quality of the paper used (Malhotra, 2006).

According to Kothari (2004), the questionnaire can be revised based on the results of the pilot study. Babbie (2008) also notes that regardless of how meticulously researchers design data collection instruments, the potential for error always exists. Saunders et al. (2009) point out that for small-scale questionnaires, a minimum of 10 participants is sufficient for piloting, while for larger surveys, it is common to use between 100 and 200 responses. They also emphasize that a pilot survey can help enhance the reliability, validity, and practicality of the questionnaire. Therefore, before distributing the questionnaire to the intended respondents, a pilot survey was conducted to assess the clarity and suitability of the questions. The aim was to ensure the questionnaire was worded as clearly as possible.

Table 3.1 presents the distribution of the pilot questionnaire used in this research. The piloting process initially targeted fifteen (15) responses; however, only thirteen (13) participants from diverse backgrounds were able to participate. Twelve out of fifteen respondents (92%) were familiar with construction sectors the contractors, government agencies, local authorities, architect, engineer and quantity surveyor are directly involved in construction while PhD candidates from similar specialisation were doing research in construction sector. Thus, the sample selection for piloting the questionnaire is adequate. Furthermore, no comments or suggestions for improvement were received from the respondents during the pilot study, indicating that the questionnaire was clear and appropriate for the intended research. Therefore, no revisions to the questionnaire were required before the actual data collection.

Table 3.1
Sample Number of Piloting Questionnaire

| *Respondents* | *Targeted* | *Cooperated* |
|---|---|---|
| PhD Candidates | 1 | 1 |
| Contractors | 4 | 4 |
| Local Authorities | 2 | 2 |
| Government Agencies | 2 | 2 |
| Architect | 2 | 1 |
| Engineer | 2 | 1 |
| Quantity Surveyor | 2 | 2 |
| Total | 15 | 13 |

### 3.4.4 Phase 4: Development of Framework

The fourth step is to develop a framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia. The development of this framework is based on the synthesis of the results obtained from the Preliminary Study and Questionnaire survey. Expert panels from the construction industry are employed to validate the accuracy of the variables involved in framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia.

## 3.5 Analysis of Data and Presentation Technique

Once the data were collected from the sample, they were analysed to assess whether they addressed the specific research questions and objectives. As this research employed both qualitative and quantitative data collection methods, the data analysis techniques were applied accordingly to each approach and will be discussed in detail in the following sections.

In this research, the analysis of quantitative data using SPSS involved three steps: assessing the reliability of measures (Cronbach's Alpha), testing data normality and generating descriptive statistics.

*Checking the reliability of measures (Cronbach's Alpha)*

Validity and reliability are critical components in evaluating a measuring instrument, and an instrument cannot be regarded valid unless it is reliable (Tavakol & Dennick, 2011). Cronbach's alpha is a reliability assessment approach that uses only one administration to provide a precise estimate of a test's dependability (Gliem & Gliem, 2003). It was designed to assess the internal consistency of a test or scale (Tavakol & Dennick, 2011). Internal consistency represents the interrelatedness of a group of items (Schmitt, 1996) and reveals how effectively all test items assess the same underlying idea or construct (Tavakol & Dennick, 2011).

Cronbach's alpha is the average value of reliability coefficients derived for all conceivable item combinations divided into two half-tests (Gliem & Gliem, 2003). Cronbach's alpha reliability coefficients typically vary from 0 to 1 (Gliem & Gliem,

2003; Tavakol & Dennick, 2011). The closer Cronbach's alpha coefficient is to one, the more internally consistent the scale's items are (Gliem 166 & Gliem, 2003). According to Tavakol and Dennick (2011), a high coefficient alpha does not always imply a high degree of internal consistency; as the number of items on the scale increases, so does the alpha coefficient (Field 2009). There is no sacrosanct threshold of alpha that is either acceptable or undesirable. In certain circumstances, measurements with low alpha values may nevertheless be extremely useful (Schmitt, 1996).

Table 3.2
Cronbach Alpha Value for Ergonomic Risk

| No | Item | N | Cronbach Alpha Value (α) |
|---|---|---|---|
| 1 | Ergonomic Risk Factor | 6 | 0.796 |
| 2 | Effects of Ergonomic Risk | 9 | 0.928 |
| 3 | Improvement of Ergonomic Risks | 24 | 0.681 |

However, Pallant (2001) indicates that the alpha value should be better than 0.7 in order for the scale to be trustworthy in the sample. Nunnally (1978) proposes that the modest dependability scale is in the range of 0.50-0.60, but Hinton et al. (2004) and Takim (2005) consider a moderately reliable scale in the range of 0.5-0.75. Table 3.2 illustrates the dependability findings based on Cronbach's Alpha value. The results demonstrate that the Cronbach's Alpha ranges from **0.681 to 0.928,** indicating that the data obtained is correlated and credible. Thus, dependability enables confidence to continue with the analysis.

*Obtaining descriptive statistics*

Descriptive statistics are basically numerical processes or graphical tools for organizing and describing the features or components of a particular sample (Fisher and Marshall, 2009). SPSS supports a variety of descriptive statistics, including frequency distributions, measures of central trends, and score dispersion (spread) (Cavana et al., 2001; Fisher & Marshall, 2009).

Table 3.3 includes definitions of common statistics words. In this study, the mean is used to measure central tendencies, while the frequency distribution and

standard deviation are used to measure data dispersion. Aside from that, the variables are ranked using their mean values. The mean ranking is used to determine the importance of each element given by the respondents. According to Wang, Dulaimi, & Aguria (2004) all take a similar method when evaluating survey findings. According to Fisher and Marshall (2009), the mean is the average of the distribution score, which is derived by adding all of the scores and dividing the total by the number of events.

Table 3.3
Common Statistic Words

| Term | | Definition |
|---|---|---|
| Measure of central tendency | Mode | The numerical value with the greatest frequency |
| | Median | The Middle score rank ordered distribution |
| | Mean | The average score |
| Dispersion | Frequency distribution | The number of cases per category |
| | Range | The distance between the highest and lowest score |
| | Interquatile range | The range within which middle 50 percent of the score fall |
| | Standard deviation | The average difference of each score to the mean |

(Source: Fisher & Marshall, 2009)

## 3.6 Validity and Reliability of Data Collection

The validity and reliability of data collecting devices are vital for minimizing bias in study outcomes. Reliability refers to the consistency, reliability, and stability of the data gathering instrument. On the other hand, validity is concerned with the precision, efficacy, and trustworthiness of the interpreted data (Kothari 2004). The consistency of the study findings determines the research instruments' dependability and variability. To ensure the quality of this research, the research design was subjected to internal validity.

### 3.6.1 Internal Validity

Internal validity aims to establish a causal relationship, where certain conditions are thought to lead to others, as opposed to relationships that are merely coincidental (Yin, 2009). While construct validity is relevant during the data collection process, internal validity pertains to the phase of data analysis. According to Dubois and Gibbert (2010), internal validity can be strengthened through three main strategies: (1) developing a clear research framework; (2) using pattern matching by comparing observed empirical patterns with either predicted patterns or those identified in previous studies and different contexts; and (3) applying theory triangulation, which involves validating findings through multiple theoretical perspectives. Additionally, Creswell (1994) emphasizes that internal validity involves evaluating the accuracy of the information specifically, whether the data truly reflects reality.

In this research, internal validation was achieved through a well-defined research framework that outlines the strategies for data collection and analysis, as discussed earlier in this chapter.

### 3.6.2 Reliability of Data

Reliability concerns whether a specific measure yields consistent results (Johnston, 2000). As noted by Yin (2009), reliability indicates that the procedures of a study such as data collection can be repeated with the same outcomes. In other words, if researchers follow the same procedures as previously outlined, they should arrive at the same findings and conclusions. The objective of reliability is to reduce errors and biases in the research.

Therefore, the three stages outlining the research procedures namely the research design phase, data collection phase, and data analysis phase are detailed throughout this chapter to demonstrate the reliability of the data in terms of replication. The Preliminary Study (semi-structured interviews) was considered an appropriate research instrument for exploring ergonomic risk in construction industry.

## 3.7 Framework Validation

The proposed Ergonomic Risk Framework for Construction Trades in Malaysia was validated using an expert review approach. Expert validation was selected to assess the framework's relevance, clarity, completeness, practicality, and suitability for implementation within the Malaysian construction industry.

Validation is the process of assessing whether a proposed framework is appropriate, credible, and capable of achieving its intended purpose. According to Creswell and Creswell (2018), validation helps establish the accuracy, applicability, and trustworthiness of research outcomes. Similarly, Yin (2018) highlighted that expert evaluation is an effective approach for determining the relevance and practicality of a proposed model or framework.

In this study, the proposed ergonomic risk framework was validated through an expert panel review, a method widely adopted in framework development studies to assess content validity, clarity, completeness, and applicability (Okoli & Pawlowski, 2004; Skulmoski, Hartman, & Krahn, 2007). The validation process was conducted through structured interviews using a questionnaire designed to obtain expert opinions on the suitability of the framework for implementation within the Malaysian construction industry.

A total of eight (8) experts from the construction industry were involved in the framework validation process. The participants were selected based on their professional expertise, industry experience, and active involvement in construction project management and site operations within Malaysia. The expert panel comprised three (3) Quantity Surveyors, two (2) Engineers, two (2) Architects, and one (1) Project Manager. The demographic information of the respondents is presented in Table 4.25, while the sample framework validation questionnaire is included in Appendix III. The findings and analysis of the framework validation are discussed in Chapter 4, Section 4.10.

## 3.8 Summary

In summary, Chapter 3 provided a detailed of how the research was conducted from planning and data collection to validation and analysis. By combining qualitative and quantitative methods, and ensuring robust procedures at each stage, the

methodology ensures that the study's findings are scientifically sound, practically relevant, and applicable to improving ergonomic safety in Malaysia's construction industry. The next chapter will deliberate the data analysis for the Preliminary Study consisting of exploratory interviews, document analysis and questionnaire survey.

# CHAPTER 4
# FINDINGS AND DISCUSSION

## 4.1 Introduction

This chapter reports on the findings of the Preliminary Study and Data Analysis of Questionnaire Survey. Preliminary study includes two phases. Phase 1 presents the result of exploratory interviews and Phase 2 present a document analysis. While Data Analysis of Questionnaire survey presents a detailed statistical analysis of the data collected from the questionnaire survey.

## 4.2 Phase 1: Finding of The Exploratory Interviews

Semi structured face-to-face interviews were conducted to evaluate regarding ergonomic risk among the trades in the construction site. The instrument drafted was divided into three sections. The first section comprises of questions related to the background of the respondents. The second section consists of structured question to obtain information on the respondents understanding of ergonomic risk. Meanwhile in the third section the respondents were asked on their understanding of IR 4.0 in construction industry. The sample of the exploratory interview question is in Appendix 1.

### 4.2.1 Sampling for the Exploratory Semi Structured Interviews

For the purpose of the exploratory semi-structured interview, ten (10) informants from four (4) ongoing projects within the construction industry. These potential respondents included a Safety Health Officer, Site Supervisor, Architect, Quantity Surveyor, and Engineer. However, only eight (8) participants agreed to take part in the interview, resulting in a response rate of 80.00%, which is considered appropriate. Reid, Flowers, and Larkin (2005) suggest that phenomenological studies often involve a small number of participants, typically around six, to gain in-depth insights into the lived experiences of individuals. The profile of respondents is illustrated in Table 4.1.

Table 4.1
Respondent's Profile

| No | Respondent | Experience | Participation | |
|---|---|---|---|---|
| | | Years | Yes | No |
| 1 | SAFETY HEALTH OFFICER (SHO) | 10 years | √ | |
| 2 | SAFETY HEALTH OFFICER (SHO) | 10 years | √ | |
| 3 | SAFETY HEALTH OFFICER (SHO) | 8 years | √ | |
| 4 | SAFETY HEALTH OFFICER (SHO) | 15 years | √ | |
| 5 | ARCHITECT | 8 years | √ | |
| 6 | ARCHITECT | 10 years | | X |
| 7 | SITE SUPERVISOR | 15 years | √ | |
| 8 | QUANTITY SURVEYOR | 10 years | √ | |
| 9 | QUANTITY SURVEYOR | 20 years | | X |
| 10 | ENGINEER | 15 years | √ | |
| **TOTAL RESPONSE** | | | **8** | |

In addition, six out of eight respondents (75%) have at least ten years of experience. This indicates that the data collected are reliable, as the majority of participants have extensive experience over a decade in managing construction projects or working within the construction industry.

### 4.2.2 Findings of Semi Structured Interview

Eight respondents were interviewed to ascertain to what extent they address Ergonomics during their design of labour-intensive construction projects. Questions 1 to 2 were broad-based question with regards to H&S. These questions were asked to put the interviewee at ease, knowingly that they should not have had any difficulty answering these common questions. Questions 4 to 11 were focused on Ergonomic knowledge and understanding, and to what extent Ergonomics was applied in their designs. These question results will be discussed in turn.

#### *4.2.2.1 Health and Safety Important on a Construction Site*

Table 4.2
Health and Safety Important on Construction Site

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Important to make sure all parties in construction site safe |
| 2 | SAFETY HEALTH OFFICER (SHO) | First, its important due to construction site condition, and there are lot of risk can lead to the accidents |
| 3 | SAFETY HEALTH OFFICER (SHO) | To make sure all works smooth in the construction site |
| 4 | SAFETY HEALTH OFFICER (SHO) | Because workers need to be train and well known their working environment |
| 5 | ARCHITECT | The design need to practically suit the environment |
| 6 | SITE SUPERVISOR | To make sure all works smooth in the construction site |
| 7 | QUANTITY SURVEYOR | Important can avoid additional spending on treatment |
| 8 | ENGINEER | Important in other to avoid any injuries |

According to the Table 4.2, Health and Safety is important to all the parties which agrees by respondent SHO 1 and SHO 2. While SHO 3 and SHO 4 indicate that safety and health will help works on site smooth and workers also need to be train and well known their working environment. In addition, respondent architect state that safety and health vital due to the design need to practically suit the environment. Whilst, site supervisor also agreed with SHO 3 that important to make sure all works smooth in construction site. Besides, respondents' quantity surveyor explained that safety and health important because can avoid additional spending on treatment. Lastly, respondents engineer said that safety and health important to avoid any injuries. Alejo et al. (2024) also noted that effective safety measures, such as training and proactive hazard mitigation, contribute to safer and more efficient working environments in construction Thus, from the Table 4.2, can be conclude that safety and health important and agreed by all the respondents.

#### *4.2.2.2 Type of Injuries Have You Encountered or Heard Of*

Table 4.3
Type of Injuries Encountered and Heard

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Tools fall onto workers leg |
| 2 | SAFETY HEALTH OFFICER (SHO) | workers collapse due to high temperature |
| 3 | SAFETY HEALTH OFFICER (SHO) | Small day to day injuries working with steel, back pain from picking up cement |
| 4 | SAFETY HEALTH OFFICER (SHO) | Lower back pain due to brick lifting and other heavy materials |
| 5 | ARCHITECT | Fingers are common injuries |
| 6 | SITE SUPERVISOR | Hand injuries |
| 7 | QUANTITY SURVEYOR | Wrist injuries |
| 8 | ENGINEER | Fatalities, machineries suddenly fall at workers |

Table 4.3 above shows the type of injuries that encounter and heard on site by the respondents. Based on respondent's engineer, state that had encounter with fatalities which machineries suddenly fall at workers. In addition, respondent SHO 1 and SHO 2 explained that encountered tools fall onto workers leg and workers collapse due to high temperature. Also, respondent SHO 3 and SHO 4, indicate that small day to day injuries working with steel, back pain from picking up cement and lower back due to brick lifting and other heavy materials. However, respondent architect state that fingers are common injuries, furthermore respondent site supervisor and quantity surveyor also claim that hand and wrist injuries encounter by workers at site. Akhtar (2025) also agreed that types of injuries encountered and reported on site. Construction workers often sustain musculoskeletal pain in the lower back, shoulders, and knees due to high-risk postures and repetitive tasks; contact with objects and equipment is also a common injury mechanism. Therefore, Table 4.3 clearly shows that most injuries encountered are hand area and back pain.

#### *4.2.2.3 Definition Ergonomics*

Table 4.4
Definition of Ergonomics

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | I would say ergonomic is safe working environment |
| 2 | SAFETY HEALTH OFFICER (SHO) | To me ergonomic is how you arrange your working condition well |
| 3 | SAFETY HEALTH OFFICER (SHO) | Ergonomic provide safety to the workers |
| 4 | SAFETY HEALTH OFFICER (SHO) | Ergonomic is important guideline to make sure workers do their job in correct ways |
| 5 | ARCHITECT | Working within the boundaries of physical human attributes and abilities |
| 6 | SITE SUPERVISOR | Safe working environment |
| 7 | QUANTITY SURVEYOR | Ergonomic in construction site is where the workers have proper tools, equipment, PPE |
| 8 | ENGINEER | Something related about human body and design on working environment |

Above shows Table 4.4, illustrated understanding of ergonomics by respondents. Respondent SHO 1 and SHO 3 said that ergonomic is safe working environment and agreed by respondents site supervisor. While respondent SHO 2 and SHO 4 understand ergonomic is how you arrange your working condition and important guideline to make sure workers do their job in correct ways. Additionally, respondent architect state that ergonomic is working within the boundaries of physical human attribute and abilities and respondent engineer understand that ergonomic is something related about human body and design on working environment. Last but not least, respondent quantity surveyor said that ergonomic in construction site is where the workers have proper tools, equipment and PPE. Hence, from Table 4.4, it can be summarized that the majority of respondents have a sound understanding of ergonomics in construction sites, which aligns with established definitions emphasizing safe working environments, appropriate work design, and consideration of human physical capabilities (International Ergonomics Association, 2020; Dul et al., 2020).

#### *4.2.2.4 Common Ergonomic Problems You Have Encountered or Identified During a Project*

Table 4.5
Common Ergonomics Problem Encountered or Identified During Project

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Lower back pain problem |
| 2 | SAFETY HEALTH OFFICER (SHO) | Noise Pollution and Temperature |
| 3 | SAFETY HEALTH OFFICER (SHO) | small injuries |
| 4 | SAFETY HEALTH OFFICER (SHO) | Back pain problem |
| 5 | ARCHITECT | Workers not wearing their PPE |
| 6 | SITE SUPERVISOR | How the workers operate the plant |
| 7 | QUANTITY SURVEYOR | Heavy material lifting |
| 8 | ENGINEER | Handling of machineries and plant |

Table 4.5 shows response by respondent on common ergonomic problem they encountered or identified during a project. Respondent SHO 1 and SHO 4 agreed that lower back pain and back pain are common ergonomic problem encountered during the project. While, respondent SHO 2 said that noise pollution and temperature common ergonomic occurred during project. Meanwhile, respondent quantity surveyor state that heavy material lifting is common ergonomic in construction project. Additionally, respondent architect, site supervisor and engineer explained that their common ergonomics during projects are workers not wearing their PPE, how the workers operate the plant and handling of machineries. Therefore, Table 4.5 clearly indicates that construction projects are associated with multiple ergonomic problems, including back pain, heavy material lifting, environmental stressors, improper machinery handling, and PPE non-compliance, which are consistent with findings reported in previous construction ergonomics studies (Dong et al., 2020).

#### *4.2.2.5 Responsibility for Mitigating Ergonomic Risks*

Table 4.6
Opinion on Who Should be Responsible for Mitigating Ergonomics Risk

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Workers need to be responsible as we provide all the necessary equipment |
| 2 | SAFETY HEALTH OFFICER (SHO) | I think everyone is, we should be discipline |
| 3 | SAFETY HEALTH OFFICER (SHO) | Safety Health Officer should be the one, need to be alert all the incoming dangerous |
| 4 | SAFETY HEALTH OFFICER (SHO) | Me, my self should take action regarding on safety and health |
| 5 | ARCHITECT | Workers should be responsible on themselves |
| 6 | SITE SUPERVISOR | Project team leader should be responsible, makesure all teamworks follow safety requirement |
| 7 | QUANTITY SURVEYOR | Safety Health officer and site supervisor need to take action on the workers safety and health |
| 8 | ENGINEER | Safety management should be responsible on workers safety and site condition |

According to the table 4.6 above, indicate that majority all the parties should take part and responsible for mitigating ergonomic risk. Hence Table 4.6 indicates that mitigating ergonomic risks is a shared responsibility among workers, safety officers, supervisors, and management, which is consistent with previous studies emphasizing collective involvement in construction safety management (Zulkiflee et al., 2020).

#### *4.2.2.6 Implementation Ergonomics Principles in Design*

Table 4.7
Implemented Ergonomic Principles in Design

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Yes, I have. Toolbox talk is held every morning before start work on site. |
| 2 | SAFETY HEALTH OFFICER (SHO) | Yes, I have. Toolbox talk is held every morning before start work on site. |
| 3 | SAFETY HEALTH OFFICER (SHO) | Yes, I have. Toolbox talk is held every morning before start work on site. |
| 4 | SAFETY HEALTH OFFICER (SHO) | Yes, I have. Toolbox talk is held every morning before start work on site. |
| 5 | ARCHITECT | Yes, our site held toolbox talk every morning. |
| 6 | SITE SUPERVISOR | Yes, I have. Toolbox talk is held every morning before start work on site. |
| 7 | QUANTITY SURVEYOR | Yes, our site held toolbox talk every morning. |
| 8 | ENGINEER | Yes, our site held toolbox talk every morning. |

Above, Table 4.7 shows the implemented ergonomic principles in design, with the majority of respondents indicating that daily toolbox talks were held before work. Toolbox talks and daily safety briefings are commonly used safety communication strategies that involve short, routine discussions on workplace hazards, ergonomic risk factors, safe work procedures, and preventive measures. These interventions have been shown to improve workers' safety awareness, strengthen hazard recognition, and promote safer work practices, making them effective tools for reducing occupational risks (Haslam et al., 2020).

#### *4.2.2.7 Courses Have You Attended with Regards to Ergonomics*

Table 4.8
Course Attended with Regards Ergonomics

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Niosh, Ergonomic Risk Assesment |
| 2 | SAFETY HEALTH OFFICER (SHO) | Niosh, Ergonomic Risk Assesment |
| 3 | SAFETY HEALTH OFFICER (SHO) | Niosh, Ergonomic Risk Assesment |
| 4 | SAFETY HEALTH OFFICER (SHO) | Niosh, Ergonomic Risk Assesment |
| 5 | ARCHITECT | None |
| 6 | SITE SUPERVISOR | None |
| 7 | QUANTITY SURVEYOR | None |
| 8 | ENGINEER | None |

Based on Table 4.8, all Safety Health Officers attended NIOSH and ergonomic risk assessment courses, while other respondents had not received such training. Formal ergonomics training has been shown to significantly improve workers' risk awareness and safety behaviors, supporting the suggestion that all construction personnel should attend ergonomics courses to enhance workplace safety (De Silva & Voon, 2021).

Additionally, safety and Health Officers (SHOs) play a critical role in promoting workplace safety and health by identifying hazards, conducting risk assessments, and implementing preventive measures. Participation in ergonomics-related training enhances SHOs' knowledge and competency in recognizing ergonomic risk factors and applying appropriate control measures. Such training has been found to improve ergonomics awareness and workplace practices, thereby contributing to better hazard identification and risk management (R. Md Sirat et al., 2018). Equipped with this knowledge, SHOs can effectively communicate ergonomic risks to workers through toolbox talks and daily safety briefings. These brief and structured discussions provide opportunities to raise awareness of workplace hazards, reinforce safe work procedures, and encourage the adoption of safer work behaviours. Consequently, ergonomics

training, ergonomic risk assessment activities, and regular safety communication interventions collectively contribute to improving workers' risk awareness and fostering a positive safety culture (Haslam et al., 2020).

#### *4.2.2.8 The Importance of Formal Training on Ergonomics Principle Among Workers*

Table 4.9
Formal Training on Ergonomics Principles is Important

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 2 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 3 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 4 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 5 | ARCHITECT | Yes |
| 6 | SITE SUPERVISOR | Yes |
| 7 | QUANTITY SURVEYOR | Yes |
| 8 | ENGINEER | Yes |

According to Table 4.9, the majority of respondents agreed that formal training on ergonomic principles is vital. This finding is consistent with previous studies, which emphasize that structured ergonomics training enhances workers' awareness of ergonomic risks, improves safe working practices, and reduces the incidence of work-related musculoskeletal disorders in construction sites (Ojha et al., 2020; Ozorhon & Karahan, 2022).

#### *4.2.2.9 Ever Come Across Term Industrial Revolution (IR 4.0) and The Challenge Facing and Benefit of IR 4.0*

Table 4.10
Ever come Across Term Industrial Revolution (IR 4.0)

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 2 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 3 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 4 | SAFETY HEALTH OFFICER (SHO) | Yes |
| 5 | ARCHITECT | Yes |
| 6 | SITE SUPERVISOR | Yes |
| 7 | QUANTITY SURVEYOR | Yes |
| 8 | ENGINEER | Yes |

In accordance with Table 4.10, the majority of respondents indicated that they have come across the term Industrial Revolution 4.0 (IR 4.0). The finding that the majority of respondents are familiar with the term Industrial Revolution 4.0 (IR 4.0) reflects the increasing penetration of digital transformation concepts within the Malaysian construction industry. This aligns with previous studies indicating that awareness of IR 4.0 among construction stakeholders is gradually improving, largely driven by national-level initiatives such as the Construction 4.0 Strategic Plan (2021–2025) and the promotion of digital technologies including Building Information Modelling (BIM), Industrialised Building System (IBS), and other smart construction tools (Construction Industry Development Board Malaysia, 2021; Oesterreich & Teuteberg, 2020). Empirical evidence further suggests that Malaysian contractors generally demonstrate moderate to increasing awareness of IR 4.0 concepts, although the level of adoption remains uneven across organisations, particularly between large and small contractors (Demirkesen & Tezel, 2021).

In addition, the emergence of IR 4.0 in construction is increasingly linked to ergonomic considerations, as the integration of automation, wearable sensors, and digital monitoring systems can help reduce workers' physical workload, improve posture monitoring, and minimise exposure to repetitive or high-risk manual tasks. However, some studies also highlight that digitalisation may introduce new ergonomic

challenges, such as increased screen-based work, cognitive workload, and human–technology interaction risks, which require proper ergonomic risk assessment and intervention to ensure worker well-being remains protected during industry transformation.

Table 4.11
The Challenge Facing and Benefits IR 4.0

| No | Respondent | Response/Answer |
|---|---|---|
| 1 | SAFETY HEALTH OFFICER (SHO) | Challenge facing would be training requirement but can give benefits to workers on handling system |
| 2 | SAFETY HEALTH OFFICER (SHO) | Resistant on IR 4.0 is they don't want any change but I believe IR 4.0 can reduce accidents |
| 3 | SAFETY HEALTH OFFICER (SHO) | The challenge is workers don't clear on the benefit of IR 4.0, benefits maybe can reduce numbers of workers on site |
| 4 | SAFETY HEALTH OFFICER (SHO) | Training implementation would be quite difficult, maybe can improve site safety |
| 5 | ARCHITECT | Can increase cost but raising standard and productivity on site |
| 6 | SITE SUPERVISOR | Unclear on the challenges and benefit |
| 7 | QUANTITY SURVEYOR | For me most of workers don't understand well on IR 4.0 plus can increase cost, however can reduce risk |
| 8 | ENGINEER | Not so clear on this |

Table 4.11 higlights the challenge facing and benefits IR 4.0 response by respondent. Majority of the respondent (SHO 3, site supervisor and engineer) clarify that workers unclear on the benefits, also they themselves unclear on this issue which agreed by Demirkesen & Tezel (2021) and Scholten & Smith (2021). However, respondents SHO 1, SHO 2 and SHO 4 indicated that the challenges faced would be the need for training and the workers' resistance to change. Plus, respondent architect said that can increase cost but raising standard and productivity on site which align with previous studies (Oesterreich & Teuteberg, 2020). Lastly, the quantity surveyor

respondent mentioned that most workers have limited understanding of IR 4.0, which may lead to higher costs but can help minimize ergonomic risks.

## 4.3 Data Analysis of Questionnaire Survey

This phase presents a detailed statistical analysis of the data collected from the questionnaire survey. As mentioned in chapter 1, the aim of this research is to propose framework of ergonomic risk factor among the trades at construction site in Malaysia. Based on the aim and data collected from literature and preliminary study, the questionnaires were prepared to capture 4 objectives of the study.

### 4.3.1 Response Rate

196 (100%) questionnaires were distributed to the targeted respondents. From the 196 sets of questionnaires distributed to the trades within the construction sites, only 80 copies were returned (40.81%) response rate with providing useful information for the survey. According to Kantar (2023), the definition of a 'good' response rate can vary depending on context. Generally, a survey response rate between 5% and 30% is deemed acceptable, while rates above 30% are considered notably strong or significant.

The demographic characteristic is a vital component in this study. Demographic information includes age, gender and type of work are presented in the table and diagram. All selected respondents were from Bangladesh and Indonesia where some of them have difficulty in understanding and responding to questions in the form. Therefore, the Safety Health Officer (SHO) helped respondents by conducting interview sessions. After each selected respondent had answered the form, the data were extracted using the SPSS software to determine between trade and risk they had during their works in construction sites. Table 4.12 shows the summary distribution of respondents' gender, age, job description, works experience and daily works in construction site. The sample of the questionnaire survey is in Appendix 2.

Table 4.12
Summary of Socio-Demographic Data of Respondents

| **Characteristics** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Gender | | |
| Male | 76 | 95.00 |
| Female | 4 | 5.00 |
| Age | | |
| 19-29 | 7 | 8.80 |
| 30-39 | 46 | 57.50 |
| 40-49 | 25 | 31.30 |
| 50-59 | 2 | 2.50 |
| Job Description | | |
| Unskilled Labour | 17 | 21.30 |
| Skilled Labour | 63 | 78.80 |
| Work Experience | | |
| 3-8 | 25 | 31.30 |
| 9-14 | 41 | 51.30 |
| 15-20 | 14 | 17.50 |
| Daily Works | | |
| Masonry/Bricklayer | 26 | 32.50 |
| Concreting | 8 | 10.00 |
| Roofing | 8 | 10.00 |
| Painting/Plastering | 8 | 10.00 |
| General Workers | 6 | 7.50 |
| Electrician | 8 | 10.00 |
| Barbender | 8 | 10.00 |
| Plumber | 8 | 10.00 |

## 4.4 Demographic Information

### 4.4.1 Participant Gender

From Table 4.12, majority of the respondents were male [76 (95.00%)] while female was very few [4 (5.00%)]. This is because most construction work is strenuous and requires strength which is why it attracts more males than females as seen in this study. In construction industries female considered not to be involve this career as its need high mentally and physically to resist the entire situation and there are several factors that support this circumstance. “External factors include nature of the industry, working conditions, and sexist attitudes among industry players that make a construction career unattractive” (Florence Yean, Yng Ling & Yeu Pei Poh, 2004). This indicate that various factors become barrier to the women and the perception the participant in the construction industries make this career not interest by female. Furthermore, the involvement of men is substantially higher than women. “A survey carried out in the UK construction industry shows that the ratio between male and female management staff is 6%:94%” (Kanchana Ginige et al., 2008). CIDB Malaysia (n.d) also shows the similar result with their statistic of active construction personnel by gender and jobs. Their data shows that general female workers foreign is 1,233 out of male 110,169 numbers and follows by local general female workers with 22,517 out of male 336,465 numbers.

### 4.4.2 Respondent’s Age

From the findings, [46 (57.50%)] respondents were aged between 30-39 years, [25 (31.30%)] were between 40-49 years, [7 (8.80%)] were between 19-29 years and only [2 (2.50%)] were 50-59 years as shown in Table 4.13. Abdul Hamid et al. (2018) explained in his studies, according to respondents, the majority of workers in their organization are between the ages of 31 and 40 (61%). Most firms favor hiring individuals between 31 and 40 years old. Thus, the company requires skilled workers, and those interested in working in construction should equip themselves with relevant skills in order to be competent.

### 4.4.3 Job Description

The study established in the stud, majority of the respondents [63 (78.80%)] is skilled labour and [17 (21.30%)] is unskilled labour. As we know any construction got various of elements and need different trades to complete the works accordingly. Therefore, skilled labour is vital to make sure the quality and productivity of the works as Ahmed, Houqu & Sobuz (2017) said that workers are the essential fuel for the operation of the construction industry, and skilled workers are the heart of construction explained that skilled labour will determine the outcomes of the project. In addition, skilled labourers are people that have served an apprenticeship, practise the trade learned activity, and, because of their knowledge and vocational capacity, are given tasks that are particularly difficult and require a lot of experience that involve different trades of specialisation (Mohd Fateh, 2022).

### 4.4.4 Years of Work in Construction Industry

The study established in the study majority of the respondents [41 (51.30%)] had work experience of between 9 and 14 years, [25 (31.30%)] years 3-8 years and [14 (17.50%)] only works 15-20 years. Table 4.13 shows that respondents with 9-14 years' experience is the majority as per shown in previous figure the majority age of respondents is 30-39 years old and that is the favor range of age employed by the employer. Respondents with 9-14 years shows less than 9-14 years as Abdul Hamid et al (2017) stated that young people actively involved in the process of earning and job mobility, where most of them were paid low which cause them to move into better paid employment. Workers with working experience 15-20 years is less than 9-14 years because those workers retire early due to the nature of construction work and also due to injuries and or disabilities arising from the work (Ndiwa, 2019). This sentiment has been proved by Brenner,H & Ahern,W (2000) who found out that the construction industry has high levels of early retirement due to permanent disability.

### 4.4.5 Daily Works in Construction Site

According to Table 4.12, shown that majority of respondents is masonry or bricklayer [26 (32.50%)] and [8 (10.00%)] are concreting, roofing, painting or

plastering, electrician, barbender and plumber. While general workers are the least [6 (7.50%)]. Lop et al. (2017) briefly explained that bricklayer, plasterer, painter, concreter, carpenter, roofer and masonry exposed to ergonomic risk and lead to the MSDs. Yu Tao et al. (2024) indicated in his studies, different trades of workers, such as rebar workers, formwork workers, concrete workers, and component decorators, are involved in the construction process. They execute demanding manual tasks and are exposed to ergonomic risks.

Table 4.13
Daily Works Strenuous

| Daily Works Strenuous | Mean | Standard deviation | Rank |
|---|---|---|---|
| Rotation | 4.47 | 0.551 | 1 |
| Heavy Lifting | 3.89 | 0.827 | 2 |
| Sliding | 3.23 | 1.321 | 3 |

Table 4.13 shows the trades having daily works strenuous in their daily works. Rotation with rank 1 is the most works strenuous having by them with mean 4.47 (0.551). While rank 2 is Heavy lifting with mean 3.89 (0.827) and sliding with mean 3.23 (1.321) is rank 3. According to Lop et al (2017), In their studies, bricklayer daily works is rotation, and also heavy lifting. This shows that eventhough with the one different trade but it can contribute various of works strenuous.

### 4.4.6 Working Hours in a Day

Table 4.14
Working Hours in a Day

| Working hours in a day | Strongly Agreed |
|---|---|
| 8 hours | 80 |
| 4 hours | 0 |
| 6 hours | 0 |
| 12 hours | 0 |
| More than 12 hours | 0 |

Based on the Table 4.14, its clearly shows that working hours of the trades is 8 hours with Strongly Agree (80) . According to the Roger W (2004), in his studies. The finding is workers must work for 8 hours every day according the Labor Act of 2007. This also supported by Law of Malaysia Act 265 Employment Act 1955 (2023).

### 4.4.7 Break During Working Hours

Table 4.15 shows 1 hour is the majority the trades breaks during their working hours with Strongly Agreed (80). According to Ndiwa (2019), Majority of workers taking break and upon further investigation, it was discovered that breaks are only allowed by supervisors/developers during lunch hours, and work resumes following. In addition, workers must work for 8 hours every day according the Labor Act of 2007. Working long hours without a break leads to fatigue, as well as safety and health issues. Fatigue prevents workers' ability to perform their duties, impacting judgment, productivity, working efficiency, and quality (Roger W, 2004). Fatigue can also cause significant skilled accidents, resulting in worker injury and even fatality.

Table 4.15
Breaks During Working Hours

| Breaks during working hours | Strongly Agree |
|---|---|
| 1 hours | 80 |
| 2 hours | 0 |
| 3 hours | 0 |
| 4 hours | 0 |
| 5 hours | 0 |

## 4.5 Ergonomic Risk Factor

### 4.5.1 Understand of Ergonomic Risk

Table 4.16 establish that all the trades understand what is ergonomic risk with frequency eighty (80). From the results we can see those trades aware what is ergonomic risk. This is due to the tool box training that have been held before they start the works at construction site. As explained by Amit Ojha et al (2020) construction workers' safety depends on their ability to detect and assess risks. Safety training enhances workers' awareness of common risks on construction sites and improves their risk awareness knowledge.

Table 4.16
Understand of Ergonomic Risk

| Do you understand what is Ergonomic Risk | Frequency | Percentage % |
|---|---|---|
| Yes | 80 | 100.00 |
| No | 0 | 0.00 |

### 4.5.2 Encounter Ergonomic Risk

Table 4.17
Encounter Ergonomic Risk During Daily Workers

| Ergonomic Risk | Mean | Standard deviation | Rank |
|---|---|---|---|
| Repetition/Awkward | 4.67 | 0.471 | 1 |
| Extreme Temperature | 3.91 | 1.352 | 2 |
| High Task Repetition | 3.86 | 1.310 | 3 |
| Contract Stress | 3.60 | 0.805 | 4 |
| Forceful Exertation | 3.51 | 1.201 | 5 |
| Vibration | 1.96 | 1.354 | 6 |

According to the Table 4.17, we can observe that Repetition or Awkward is the majority of Ergonomic Risk having by the trades with Rank 1 and mean 4.67 (0.471). Follows with Wxtreme Temperature with mean 3.91 (1.352) and the Rank is 2. While Rank 3 is high Task Repetition and the mean is 3.86 (1.310). Next Rank is 4, Contract Stress with mean 3.60 (0.805). Then Rank 5 and 6 are Forceful Exertation and Vibration. Both risks are with mean 3.51 (1.201) and 1.96 (1.354). Teena Babu and Annie Sonia xavier (2018), agreed that force & repetition are the major factor ergonomic risk factors and their analysis were done by using RII method used for ranking the factors. In addition, (Michigan Occupational Safety and Health Administration, 2015) also stated the same thing which is major ergonomic risk factors are Force, Repetition, and Posture. Other potential ergonomic risk factors include vibration, contact stress, sustained exertions, and cold temperatures. Coventionally, manpower in construction industry suffer into MSD but not have been notice by themself.

### 4.5.3 Experience Body pain

Table 4.18 shows respondents by trades experience body pain in last 6 months. The charts show that majority of masonry or bricklayer with frequency 16 having body pain in last 6 months. Follow by concreting, roofing, electrician, barbender and plumber with frequency 8. While general workers are 6 frequencies. However, painting or

plastering with 8 frequencies do not having body pain in last 6 months. According to Lop et al (2019) trades with ergonomic risk of repetitive, awkward posture and force exertion is tend to have lower and upper back for that reason, masonry is the majority respondents having pain in last 6 months because they keep repeat the same movement.

Table 4.18
Respondents by Trades Experience Body Parts

| **Trades** | **Yes** | **No** |
|---|---|---|
| General Workers | 6 | 0 |
| Concreting | 8 | 0 |
| Masonry | 13 | 0 |
| Painting | 0 | 8 |
| Roofing | 8 | 0 |
| Electrician | 8 | 0 |
| Barbender | 8 | 0 |
| Plumber | 8 | 0 |
| Bricklayer | 13 | 0 |

### 4.5.4 Affected Body Parts

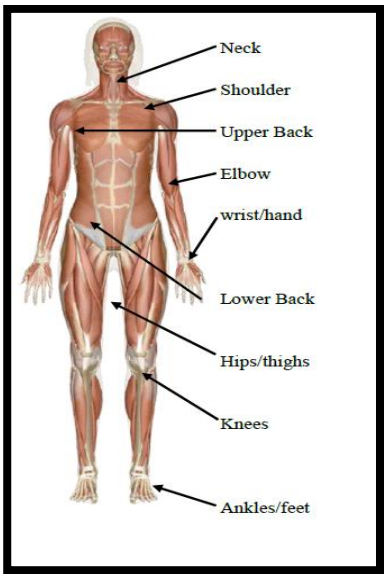


Figure 4.1 Body Diagram

Figure 4.1 shows the diagram of body part where the respondents are given this diagram to indicated their most affected body as per shown in Table 4.19.

Table 4.19
Pain in Body Parts

| **Body Parts** | **Mean** | **Standard deviation** | **Rank** |
|---|---|---|---|
| Lower Back | 4.00 | 1.212 | 1 |
| Shoulder | 3.89 | 0.827 | 2 |
| Upper Back | 3.68 | 1.300 | 3 |
| Ankles or Feet | 3.53 | 0.927 | 4 |
| Wrist or Hand | 3.51 | 1.079 | 5 |
| Knees | 3.35 | 1.045 | 6 |
| Hips or Thigh | 3.03 | 1.242 | 7 |
| Elbow | 3.00 | 1.125 | 8 |
| Neck | 2.99 | 1.278 | 9 |

Table 4.19 shows that the lower back (Mean = 4.00) is the most affected body region, followed by the shoulder (Mean = 3.89) and upper back (Mean = 3.68). This indicates that musculoskeletal discomfort among construction workers is primarily concentrated in the spinal and upper body regions, which are typically associated with manual handling, bending, lifting, and overhead work.

Among the different construction trades, masonry and bricklaying workers were identified as the most affected groups, as they recorded the highest number of “Yes” responses and were strongly associated with higher mean scores for lower back (Mean = 4.00, Rank = 1), shoulder (Mean = 3.89, Rank = 2), and upper back (Mean = 3.68, Rank = 3). This pattern suggests that masonry and bricklaying activities significantly contribute to musculoskeletal strain, particularly due to frequent forward bending that increases lower back stress, repetitive lifting of bricks and cement materials that results in spinal compression, and continuous handling of heavy loads that leads to shoulder fatigue and strain.

The moderately affected trades, comprising concreting, roofing, electrician work, bar bending, and plumbing, were closely associated with intermediate levels of

musculoskeletal discomfort, particularly in the ankles and feet (Mean = 3.53, Rank = 4), wrists and hands (Mean = 3.51, Rank = 5), and knees (Mean = 3.35, Rank = 6). This pattern indicates that these occupations typically involve prolonged standing on unstable or uneven surfaces, frequent repetitive hand tool usage such as tying, drilling, and mixing, as well as sustained kneeling during installation and finishing activities. In addition, workers in these trades are often exposed to physically challenging and awkward working environments, including rooftops, trenches, and scaffolding, which further contribute to cumulative ergonomic strain.

The lower affected body regions, including the hips/thigh (Mean = 3.03) elbow (Mean = 3.00), and neck (Mean = 2.99), recorded comparatively lower mean scores than other body parts, indicating that these areas experience less frequent extreme postural loading compared to the spine and shoulder regions. However, the presence of moderate mean values still suggests that workers are exposed to a degree of discomfort in these regions, likely due to prolonged static postures and repetitive manual tasks commonly associated with construction activities.

The least affected trade was painting, as respondents reported no pain experience (0 “Yes” responses) in Table 4.19, indicating minimal musculoskeletal complaints within this group. However, the overall body part analysis in Table 4.20 still reflects general neck and upper limb involvement across the sample, suggesting that painting activities in this study context may involve relatively lower physical intensity, reduced exposure duration compared to more structural trades, or variations in task execution that help minimise ergonomic strain.

According to Lop et al (2017), lower back, shoulder, wrist and shoulder are the most affected body pain having by the trades which this pain is correlated to the MSD’s sysmptom. In addition, Daruis et al. (2019) also agreed that lower back pain is the most affected body pain by the workers.

## 4.6 Health and Safety Management

Table 4.20 shows the summary of safety management in construction site. From the table we can conclude that all the workers are providing with the PPE with [70 (100%)]. According to Shazwan Hashim & May (2018) respondents acknowledge the risks of construction sites and emphasize the need of using personal protective equipment (PPE) when working onsite. Apart of that the contractor acknowledged that

training is a mandatory requirement for construction companies to ensure workers have the necessary knowledge to work safely on the construction site.

PPE provided for them are safety helmet, safety vest, safety shoes and safety harness with each of the PPE provided [70 (100%)]. This also agreed by Shazwan Hashim & May (2018) ,as his studies also shows the similar result which PPE provided on site are Safety Helmet, Safety Boots, Safety Harness and protective clothing. While other protective gears are sometimes to be provide according to the task or trades work on site.

According to the table 4.20, all respondent agreed that accident reported in site. This also proved by DOSH Malaysia n.d, there are accident reported on site to the DOSH every month. From the table we can see that majority of respondents reported accidents to supervisor [69 (98%)]. Follows by Workmate [63 (90%)]. Last but not least is foreman with [1 (1%)].

Respondents agreed that their employer put measure on site to prevent accidents. This also have been discussed before whereas respondents agreed that PPE are provided to them for each of them on site. In addition the table also shows the measure by their employer in prevent accidents. The measure are following OSHA guidelines, Safety training, Crew safety meeting, Utilize protective clothing & gear, maintain equipment and tools and lastly maintaining the workspace clean.

Table 4.20
Summary of Safety Management

| **Characteristics** | **Frequency** | **Percentage (%)** |
|---|---|---|
| PPE Necessary | | |
| Yes | 80 | 100 |
| No | 0 | 0 |
| PPE Provided | | |
| Safety Helmet | 80 | 100 |
| Safety Vest | 80 | 100 |
| Safety Shoes | 80 | 100 |
| Safety Harness | 80 | 100 |
| Accidents Reported to | | |
| Foreman | 1 | 1.30 |
| Workmate | 73 | 91.3 |
| Supervisor | 79 | 98.8 |
| DOSH | 80 | 100 |
| Doctor | 80 | 100 |
| Employer put measure to prevent accidents | | |
| Yes | 80 | 100 |
| No | 0 | 0 |
| Measure to prevent accidents | | |
| OSHA Guideline | 80 | 100 |
| Safety Training | 80 | 100 |
| Crew Safety Meeting | 79 | 98.8 |
| Utilize Protective Clothing & Gear | 80 | 100 |
| Maintain Equipment & Tools | 48 | 60 |
| Workspace Clean | 69 | 86.3 |

### 4.6.1 Safety Management in Construction Site

According to the Table 4.21, Induction and, briefing on site or training when started work is Rank 1 with mean 4.05 (0.870). Respondent also agreed that workers need to be inducted on site Rank 2 and the mean is 4.04 (0.863). Employer also need put in place safety and health measure in work site is Rank 3 with mean 3.96 (0.834). All the measure above has been proved by Zulkiflee et al. (2020). In his case studies, stated that toolbox meeting induction was held every morning every month. Futhermore, he said to ensure safety goals can be achieved, safety regulations and policies are fundmental in an organization to regulate the safety of construction workers.

Table 4.21
Safety Management

| **Safety Management** | **Mean** | **Standard deviation** | **Rank** |
|---|---|---|---|
| Was there an induction/brief work at site/ training when started work at site | 4.05 | 0.870 | 1 |
| Workers need to be inducted/trained | 4.04 | 0.863 | 2 |
| Employer must put in place safety & health measure in work site | 3.96 | 0.834 | 3 |

## 4.7 Industry Revolution 4.0 (IR 4.0)

Table 4.22 provided an overview summary data of respondents for Industrial 4.0. From the table, only 34 (48%) know the term IR 4.0 and 36 (66%) do not know what exactly the term IR 4.0 and never heard about IR 4.0 in any platform. While the respondents who know the term heard about IR 4.0 from the online advertisement. Based on the summary, the respondents who know the IR 4.0 only know the terminologies of Internet of things 26 (37.10%), Sensor 25 (35.70%), Simulation 5 (7.10%), Autonomous Robots 3 (4.30), Big Data 3 (4.30%) and Cloud computing 1 (1.40%). According to Patrick ethe raj et al (2020), the terminologies listed in the table

10 are common wors. Thus, this explains why some of them heard the terminologies.

Table 4.22
Summary Data of Respondent for Industrial 4.0

| **Characteristics** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Term IR 4.0 | | |
| Yes | 39 | 48.8 |
| No | 41 | 51.2 |
| Know IR 4.0 | | |
| Online Advertisement | 39 | 47.5 |
| Others; No | 41 | 52.5 |
| Know the Terminologies | | |
| Sensor | 30 | 37.50 |
| Simulation Additive | 5 | 6.30 |
| Manufacturing | 0 | 0.00 |
| Autonomous Robots | 3 | 3.80 |
| System Integration | 0 | 0.00 |
| Building Information Modelling | 0 | 0.00 |
| Augmented Reality | 0 | 0.00 |
| Cloud Computing | 1 | 1.30 |
| Big Data | 3 | 3.80 |
| Internet of Thing (IOT) | 31 | 38.80 |

Table 4.23 shows that Unclear benefit and gain is Rank 1 with mean 3.34 (0.478). Subsequently followed by Training equipment Rank 2 and the mean is 3.26 (0.472). Rank 3 is Resistant to change with mean 3.24 (0.464). While Impact on workers is Rank 4 with mean 3.16 (0.367). Cost Implementing is Rank 5 and the mean is 3.06 (0.234). Last nevertheless least is Lack of standardization with mean 3.03 (0.168). All the challenge listed in the table 11 is proved by Demirkesen and Tezel (2021) , in their

studies. His finding on the challenge implement IR 4.0 are comparable with the table 11. Patrick ethe raj et al (2020), also proved that Malaysia has taken her step in her education system in skills related to industry 4.0 application but current manpower knowledge and skills need to undergo vigorous training including introduction of coding in school syllabus. Hence, this is shows that training is vital to give awareness to the workers in implementing of IR 4.0.

Table 4.23
Challenge Implemented of IR 4.0

| **Challenges of IR 4.0** | **Mean** | **Standard deviation** | **Rank** |
|---|---|---|---|
| Unclear benefit and gain | 3.36 | 0.484 | 1 |
| Training requirement | 3.29 | 0.482 | 2 |
| Resistance to change | 3.28 | 0.477 | 3 |
| Impact on workers | 3.20 | 0.403 | 4 |
| Cost of implementing | 3.05 | 0.219 | 5 |
| Lack of standardization | 3.03 | 0.157 | 6 |

According to the Table 4.24 there are several benefits from implementing of Industrial Revolution IR 4.0 in construction site. Raising standards and productivity is Rank 1 and the mean is 3.23 (0.423). Rank 2 is Modernising the industry with mean 3.21 (0.413). Followed by Improving site safety which is Rank 3 and mean is 3.20 (0403). Next Rank is number 4 Reducing Risk with mean 3.16 (0.367). Finally, but not least is Rank 5. They are Saving time and money and also Improving sustainability with mean 3.03 (0.168). Ghada Taher (2021) explained in his studies, industry 4.0 technologies have significant impacts for the construction sector, its businesses, the environment, and personnel. Implementing these practices not only improves productivity, efficiency, quality, and teamwork, but also enhances safety, sustainability, and decision-making, ultimately boosting the construction industry's image. As well as Aslan (2019), accidents rates can be decreased with help of industry 4.0 technologies through increasing monitoring and measurement working environment. In case, there are serious accidents, early detection and prevention can be done before the accidents occur.

Table 4.24
Benefts Implementation of IR 4.0

| **Benefits of IR 4.0** | **Mean** | **Standard deviation** | **Rank** |
|---|---|---|---|
| Raising standards and productivity | 3.26 | 0.443 | 1 |
| Modernising the industry | 3.25 | 0.436 | 2 |
| Improving site safety | 3.24 | 0.428 | 3 |
| Reducing risk | 3.14 | 0.347 | 4 |
| Saving time and money | 3.03 | 0.157 | 5 |
| Improving sustainability | 3.03 | 0.157 | 6 |

## 4.8 Development of Conceptual Framework

Figure 4.2, illustrates the conceptual framework of ergonomic risk among construction trades in Malaysia. This framework is developed based on the comparative results obtained from the questionnaire survey and the preliminary study. The framework comprises of Input ( I ), four elements ( E ) and Output ( O ) . Element 1 ( E1 ) focus on the issue or accidents occurred on site. Element 2 ( E2 ) consists of Ergonomic Risk that happened among the trades which is Input ( I ) to the E2. Whilst Element 3 ( E3 ) indicate effect of ergonomic risk. Then Element 4 ( E4 ) emphasis on prevention or improvement of ergonomic risk. Lastly, Output ( O ), refers to the outcomes or output of the research.

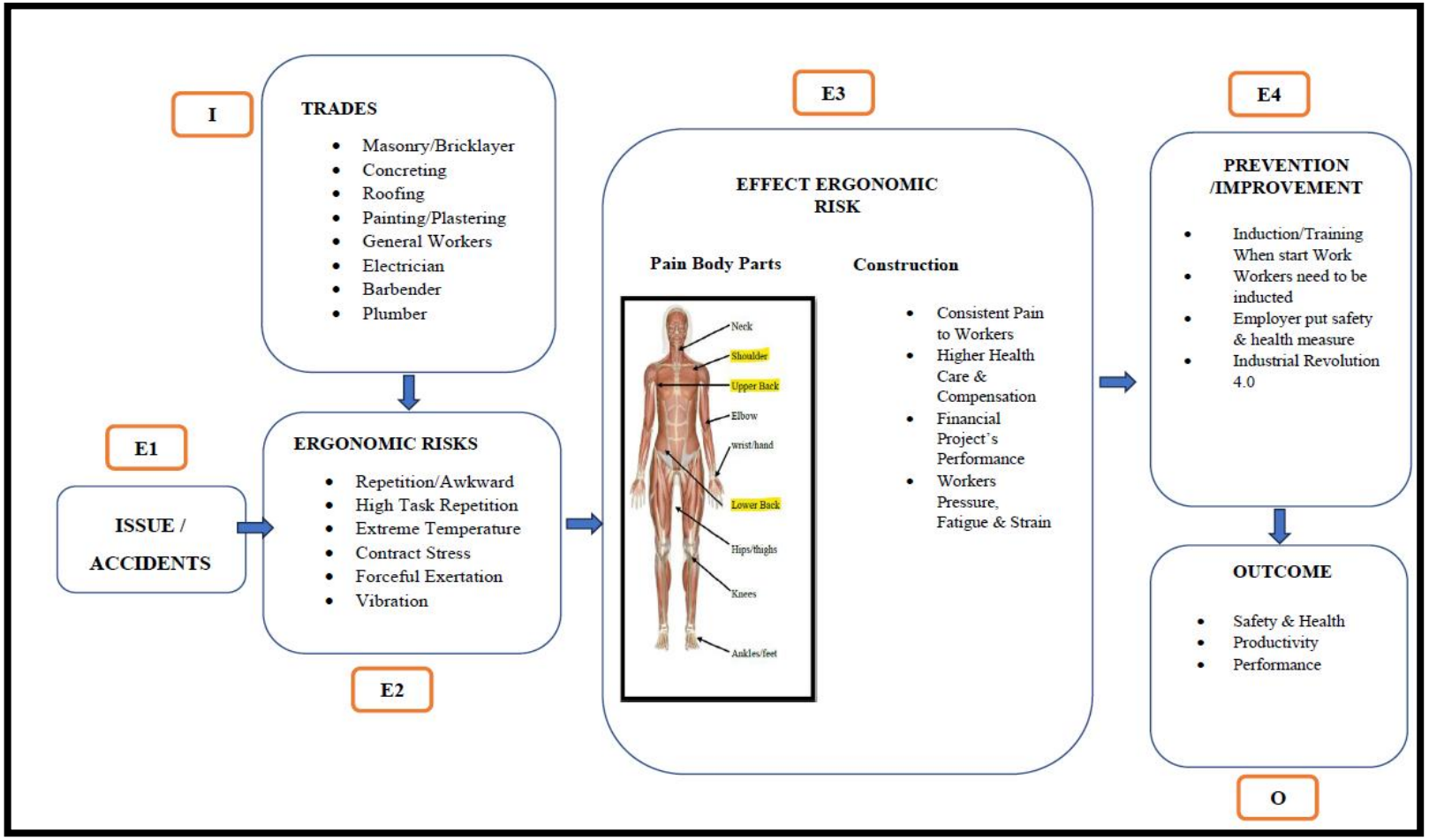



Figure 4.2 Framework of Ergonomic Risk

*Element 1 ( E1 ): Issue / Accidents*

Element 1 (E1), focus on the issue or accidents occurred on site. Abas et al (2020) stated that Major construction projects in Malaysia are exposed to dangerous conditions which can cause accidents and consequently affect the safety performance of the construction projects. The causes of accidents in construction industry are related to unique nature of the industry, human behaviour, improper site conditions, unsafe work method, equipment and procedures which affected from poor safety management. These causes could result in accidents which further cause disruption of work and decrease the work rate. Vijayakumar and Choi (2022) explained that building workers are exposed to excessive construction site dangers that can result in injuries or even death. They face different kinds of safety and health hazards whilst working in their work sites every day.

*Element 2 ( E2 ) / Input ( I ): Ergonomic Risk among the Trades*

Element 2 ( E2 ) consists of Ergonomic Risk that happened among the trades which is Input ( I ) to the E2. The three major ergonomic risk factors are force (how much you lift/push/pull), repetition (how frequently you conduct the operation), and posture (body position). Other ergonomic risk concerns include vibration, contact stress, prolonged exertion, and frigid temperatures (Lop, Mat Salleh, Yop Zain & Saidin, 2019). Anagha and Annie (2020) in their studies also agreed that the main ergonomics risk factors were uncomfortable posture, repetitive movements, and vibration. Other ergonomic risks include unpleasant static positions, muscle and tendon contact, and severe temperatures.

*Element 3 ( E3 ) : Effect of Ergonomic Risk*

Element 3 ( E3 ) indicate effect of ergonomic risk. In addition, ergonomic risks on construction sites can result in severe and traumatic joint and muscle injuries. Exposure to a single risk factor or a combination of risk variables increases the possibility of ergonomic injury or illness, commonly known as Work Related Musculoskeletal Disorders (WMSD). They can lead to long-term and serious medical issues that prevent individuals from working and enjoying life (Francis & Deepan,

2019). Typically, workers in the construction industry suffer from MSD but are unaware that they having it (Lop, Mat Salleh, Yop Zain & Saidin, 2019).

Work-related musculoskeletal injuries and disorders (WMSDs) are among the most frequently reported causes of lost or restricted work time in the construction industry. Overexertion, sprains, strains, pulls, and/or tears are all an unfortunate regular occurrence on many constructions job sites (Sneller , Ahn & Choi, 2019). According to Santarelli (2023) ergonomic hazards can cause consistent pain to workers, who often choose to work through that pain. According to OSHA, "working hurt" is among the largest problems facing construction workers today, as working hurt can not only lower productivity, but can cause lifelong pain and disability.

Workers in the construction industry are around 50% more likely to develop WMSDs. As a result, the construction industry frequently engages in higher medical expenses and compensation costs for injured workers (Dong, Betit, Dale, Barlet & Wei, 2019). To some extent, construction workers are involved with challenging tasks. Due to the construction and building industries' adaptability, diversity, and dynamic nature. Workers in the construction industry are at risk of limitations, injuries, illness, and even death due to the broad scope of their work and the complexity of the projects. Construction is one of the seven jobs with the highest incidence rates. Work-related musculoskeletal diseases (WRMSDs) affect a substantial number of employees, resulting in substantial financial losses. (Mayank Katode et al., 2021).

Accidents that occur on a construction site may create a delay in the completion of the project, which is connected to the time factor in project performance. Besides, the accident had an influence on project performance in terms of indirect workplace expenses to the company and workers. This is due to an increasing in expenditures, which has a financial effect on the project's performance (Abdul Aziz, Mohd Nordin, Ismail & Yunus, 2020). Every construction worker is likely to be temporarily unable to work as a result of relatively significant injuries or health problems sustained while working on a building site at some point. This can gradually put pressure on workers to raise their output, which opens the door for shortcuts to be taken instead of following safe work procedures that are also designed prior to the start of work (Sneller, Choi, Ahn & Choi, 2019).

*Element 4 ( E4 ) : Prevention/Improvement of Ergonomic Risk*

Then Element 4 ( E4 ) emphasis on prevention or improvement of ergonomic risk. Albarkani & Shafii (2021) observed that staff training is a work activity that can make a very significant contribution to the overall effectiveness and profitability of an organization. He, therefore, provides a systematic approach to training which encases the main elements of training. After the training program, an evaluation is carried out to ascertain the effectiveness of the "program in line with the need'' which had been identified.

One of the suggested strategies is to incorporate incentive programs into construction projects. Safety incentive programs refer to programs that reward workers for achieving certain goals related to workplace safety (Abas et al., 2020). Some studies show that safety incentive programs can improve many safety performances at the construction site. This is an initiative that rewards employees for improving their safety procedures and decreasing the number of reported injuries and incidents (Abas et al., 2020).

Other than that, Personal Protective Equipment (PPE) is equipment worn to minimize exposure to serious workplace injuries and illnesses. The PPE is also worn to reduce exposure to ergonomics-related risk factors. These injuries and illness may come from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Example of PPE equipment are such as gloves, safety glass, shoes, earplugs, hard hats, respirators, vests and full body suits. The example of the uses of PPE in workplace are such using padding to reduce direct contact with hard, sharp, or vibrating surfaces and wearing good fitting thermal gloves to help with cold conditions while maintaining the ability to grasp items easily (Ghazali et al., 2022).

Additionally, Industry 4.0 was initiated to explore how the manufacturing industry could benefit from the integration and implementation of new technologies. The concept is broad and considers many aspects of interdisciplinary technologies and collaborations, which is imperative to achieve continuous automation through different processes (Schönbeck, Löfsjögård & Ansell, 2020). Besides, Construction 4.0 also increased the productivity. Industry 4.0 promises increase in productivity through the integration of digital systems of production with analysis and communication of all data generated within an intelligent environment (Alalout et.al, 2020). Certainly, implementing Construction 4.0 can provide a slew of advantages with the internet of

things as discussed before. Worker only need to manage the tools and machine that he will be used. Eventually, will decrease hazard on workers. A well-established culture of accident prevention can be developed with help of Industry 4.0 implementation (Aslan, 2019).

*Output/Outcomes ( O ) : outcomes or output of the research.*

Output ( O ), refers to the outcomes or output of the research. As a last perspective, several elements have been identified that can impact the safety performance of the construction site. Implementing these safety elements has a variety of benefits, including reducing the frequency of accidents on the construction site, increasing productivity, completing the project on time, lowering compensation costs, and improving employee morale. Good project-level safety performance can lead to improved safety performance in the construction sector. Additional, Construction 4.0 also brings a lot of benefit.

The proposed framework is next subjected to the validation process by the Malaysian construction professionals. Although, the proposed framework has not been tested empirically in the industry, it is believed that the opinions by the experts could help to justify the necessity and the applicability of the framework in the construction project environment.

## 4.9 Framework Validation

Validation refers to the official confirmation that a framework meets a defined set of standards for a particular purpose (Sargent, 1996). In this study, validation is conducted through expert panel review, as recommended by previous researchers (Lauesen & Vinter, 2001; Tigelaar et al., 2004; Hyrkas, Appleqvist-Schmidlechner, & Oksa, 2003; Rosqvist, Koskela, & Harju, 2003; Subramoniam, Huisingh, Chinnam, & Subramoniam, 2013). The expert panel validation is carried out through a structured interview using a questionnaire. The interview was conducted with eight (8) respondents who are closely involved in the Malaysian construction industry. This includes three (3) Quantity Surveyor, two (2) Engineer, two (2) Architect and One (1) Project Manager. Table 4.25 shows the details of the 8 respondents who responded to

the validation survey and the sample of the framework validation question is in Appendix 3.

Table 4.25
Respondents Profile

| No | Respondent | Organisations | Experience |
|---|---|---|---|
| R1 | Quantity Surveyor | Consultant | 20 years |
| R2 | Quantity Surveyor | Contractor | 11 years |
| R3 | Quantity Surveyor | Contractor | 12 years |
| R4 | Engineer | Consultant | 34 years |
| R5 | Engineer | Contractor | 10 years |
| R6 | Architect | Consultant | 10 years |
| R7 | Architect | Consultant | 15 years |
| R8 | Project Manager | Contractor | 18 years |

A sample of validation questionnaire and feedback form is presented in Appendix 3**.** The first section explains the background on the framework development of Ergonomic Risk at Construction Site. The second section explain briefly the components of the Element (E). The third section is the validation questionnaire which consists of two main sets of questions.

The first section of the questionnaire can be divided into three items: *1) To rate the completeness of the framework with the five Core Issues:* Issue/Accidents (E1); Ergonomic Risk among the trades (E2); Input (I); Effects of ergonomic risks (E3); Improvement of ergonomic risk (E4) and Output/Outcomes ( O ) ; *2) To rate the appropriateness of the five issues*: Issue/Accidents (E1); Ergonomic Risk among the trades (E2); Input (I); Effects of ergonomic risks (E3); Improvement of ergonomic risk (E4) and Output/Outcomes ( O ) and *3) To rate the framework in terms of*: Ease of understanding of the framework; The ease of use; and Beneficial use of the framework to contractors or consultant. The indication level of opinion is based on a five-point Likert-scale namely 1 to 5, where 1 represented 'poor' and '5' represented 'excellent'.

The second set of questions refers to the questions that provide additional general comments on the applicability of the framework in an 'open-ended' type question. In addition, a copy of the framework is attached together with the

questionnaire. The results were transcribed verbatim and analysed by thematic content analysis method.

## 4.10 Validation Results and Discussion

Table 4.26 shows the results of the validation process for framework conducted with 8 respondents. The detail of the result is in *Appendix 3*. The validation result was divided into three items (i.e., rate the completeness of the framework with the Core Issues of accidents, risk, input, effects and improvement; rate the appropriateness of the same core issue previously; and rate the framework in terms of ease of understanding of the framework, the ease of use, and beneficial use of the framework). The result will be deliberated in turn.

Table 4.26

Results of Validation

| | Rate the completeness of the framework on the Core Issues of: | | | Rate the appropriateness of the framework on issues of: | | | Rate the framework: | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Issue/Accidents (E1)* | *Risk (E2), Input (I), Effects (E3), Improvement (E4)* | *Outcomes (O)* | *Issue/Accidents (E1)* | *Risk (E2), Input (I), Effects (E3), Improvement (E4)* | *Outcomes (O)* | *Ease of Understanding* | *Ease of Use* | *Beneficial Use* |
| Poor | | | | | | | | | |
| Satisfactory | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Good | 5 (62.6%) | 7 (87.5%) | 5 (62.5%) | 5 (62.5%) | 5 (62.5%) | 5 (62.5%) | 5 (62.5%) | 5 (62.5%) | 5 (62.5%) |
| Very Good | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Excellent | | | | | | | | | |
| ***Total*** | **8** | **8** | **8** | **8** | **8** | **8** | **8** | **8** | **8** |

***Rate The Completeness of the Framework with the 5 Core Issues***

The expert panel's initial comment on the framework concerns the rating of the framework's completeness in relation to the five (5) Core Issues it addresses. The findings on the accidents, risk, effects and improvement indicated that the majority of respondents rated this aspect as 'good'—with 62.5% and 87.5% respectively.

As for the first item, respondents R3 stated that,

*"The framework identifies the hazard and accident cause which is addresses construction site safety"*

For 2nd item respondents R3 explained,

*"The framework clearly highlights ergonomic risk and the effects it also provides effective strategies for solving the issue*"

While respondents R1 state for item 3rd,

*"The outcomes, such as reduced WMSDs, better health, increased productivity, and cost savings, are well-aligned with the frameworks"*

However, one respondent (13%) rated all item as 'satisfactory'. On the other hand, despite most of the respondents (25%) rated 'very good' for issue/accidents and Outcomes.

***Rate the appropriateness of the 4 issues: Accidents, Risk, Input, Effect and Improvement***

The results for appropriateness is 5 out of 8 respondents (62.5%) rated this issue as good. This showed that the respondents agreed that the ranking of Ergonomic Risk, Effects, Improvement and Outcomes is appropriate.

Respondents R3 claimed for 1st item that:

*"The framework is appropriate for addressing construction site accidents. It accurately identifies the key issues and hazardous conditions, such as unsafe work"*

*"The improvement strategies are appropriate but could benefit from more detailed guidance on practical implementation."* (R8)

Furthermore, respondents R1 highlighted 3rd item that,

*"The outcomes are highly appropriate, focusing on reducing WMSD, improving worker health, and boosting productivity. The framework effectively addresses safety, cost savings and better project timelines."*

Similar to previous section validation, only one respondent (13%) rated all as 'satisfactory'. On the other hand, despite most of the respondents (25%) rated 'very good' for issue/accidents, risk, input, effects, improvement and Outcomes.

Based on the results, it can be concluded that the four issues mentioned above can be considered as appropriate for the framework

***Rate the framework of ergonomic risk among trades at construction site in Malaysia.***

In terms of the ease of understanding of the framework, it was rated as 'very good' by a majority of the respondents (62.5%). The framework was mentioned as 'easy to understand' by most of the respondents (i.e., R1, R2, R3, R4 and R7). Respondents R1 and R3 claimed that:

*"Framework clearly explain the structures and the flow steps, but need more give exposure to stakeholders what meaning of ergonomic risk." (R1)*

*"The framework looks systematic, but construction teams might need more hands-on guidance and training to effectively apply it in real-time work" (R3)*

Additionally, the majority of respondents (5 out of 8) rated the usefulness of the framework as 'Good'. This view was shared by respondents R3.

*"This framework is easy to understand because the points are clear, interconnected, and visually organized."*

Last but not least, in term of beneficial of the framework was rated as 'Very Good' by the majority of respondents (5 out of 8). Respondents R4 indicate that:

*"The framework very beneficial for all partis which can help and prevent the injuries."*

In summary, the comprehensive research findings are illustrated in figure 4.13. The figure briefly shows that research identified the relationship between construction trades, ergonomic risks, their effects, preventive measures, and resulting outcomes. It begins by identifying various construction trades (e.g., masonry, concreting, roofing, general labor)

that are commonly exposed to ergonomic risks such as repetitive or awkward motions, high task repetition, extreme temperatures, contract stress, forceful exertion, and vibration.

These risks contribute to ergonomic-related issues and accidents, which primarily impact workers' musculoskeletal systems. The effects are shown through targeted pain in body parts (e.g., neck, shoulders, lower back, knees) and broader implications for the construction industry, including increased healthcare costs, reduced productivity, financial strain on projects, and physical fatigue or pressure on workers.

To mitigate these effects, the framework emphasizes preventive and improvement strategies, such as proper induction and training, employer-led health and safety measures, and the integration of technological advancements (e.g., Industry 4.0). When implemented effectively, these strategies lead to positive outcomes: enhanced productivity, improved safety, and better overall performance.

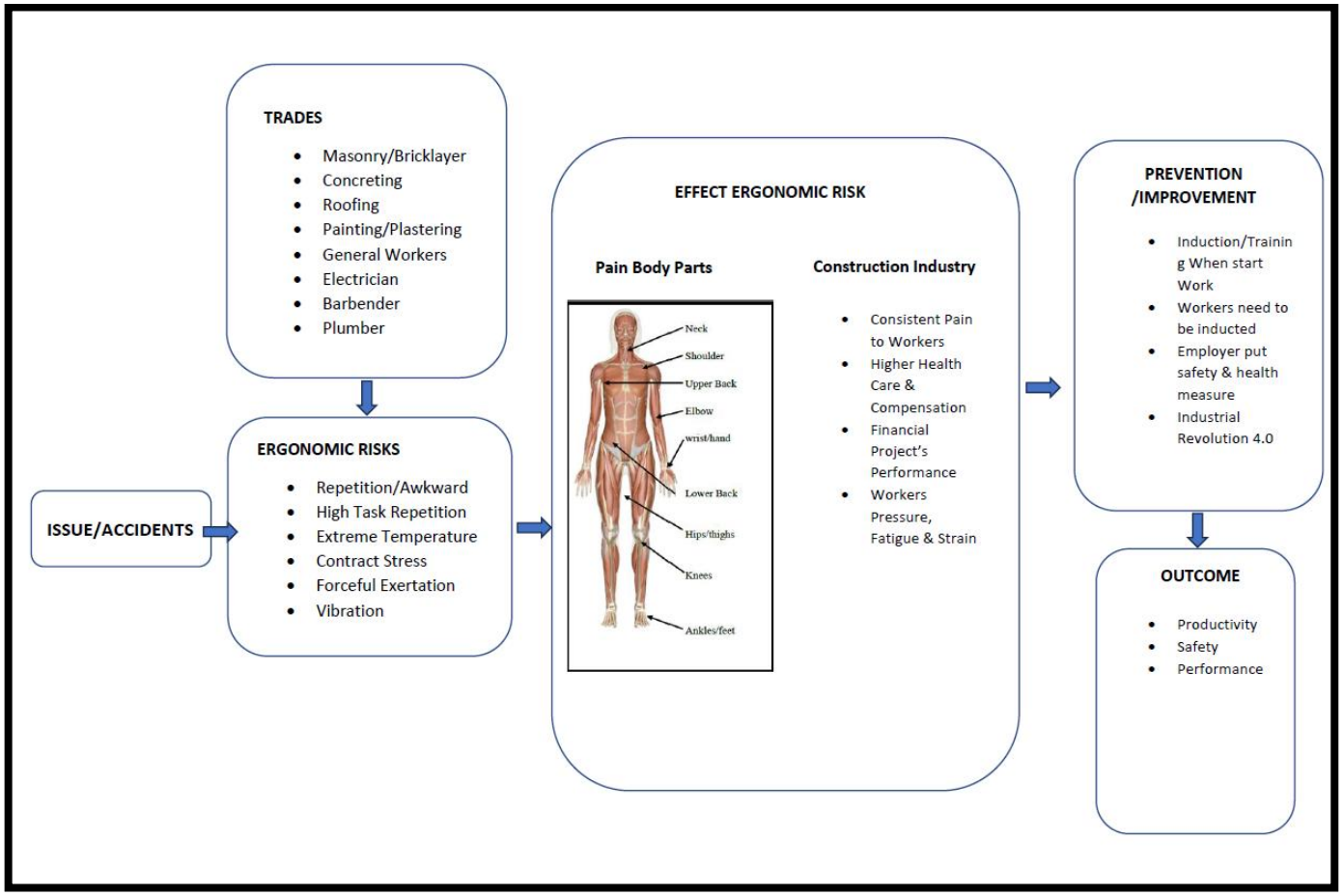



Figure 4.3 Framework of Ergonomic Risk after Validation

## 4.11 Summary

This chapter summarizes the outcomes of the preliminary study and the questionnaire survey analysis. The preliminary study was conducted in two phases, summarizing the results of the exploratory interviews and document analysis, followed by a summary of the statistical analysis of questionnaire survey data. This chapter also include questionnaire to expert panel for validation formwork.

Phase 1 presents findings from semi-structured interviews with eight experienced construction professionals to explore ergonomic risks and awareness in the construction industry. All respondents agreed that health and safety are critical on construction sites to prevent injuries, ensure smooth project operations, and reduce costs. Commonly reported injuries included lower back pain, hand and wrist injuries, heat-related incidents, and machinery-related accidents, indicating significant ergonomic risks.

Most respondents demonstrated a basic understanding of ergonomics, associating it with safe working environments, proper tools, and suitable work practices. Frequently identified ergonomic problems included heavy material lifting, poor machinery handling, noise, high temperatures, and non-compliance with PPE. Respondents agreed that responsibility for mitigating ergonomic risks should be shared among workers, safety officers, and project management.

Although Safety Head Officers had received formal ergonomic training, other professionals lacked such exposure. Nevertheless, all respondents emphasized the importance of formal ergonomic training. While all participants were aware of Industrial Revolution 4.0, understanding of its challenges and benefits was limited, with concerns related to training needs, worker resistance, and increased costs, despite recognizing its potential to improve safety and reduce ergonomic risks.

Further, Phase 2 of the preliminary study involved questionnaire data collected from 80 construction trades workers in Malaysia, achieving a response rate of 40.81%, which is considered strong. The survey aimed to support the development of an ergonomic risk factor framework for construction trades. Most respondents were male, aged between 30–39 years, predominantly skilled workers with 9–14 years of experience. Masonry and bricklaying were the most common trades, involving physically demanding tasks such as rotation, heavy lifting, and sliding.

All respondents worked an average of eight hours per day with a one-hour break,

in compliance with Malaysian labour regulations. Workers demonstrated good awareness of ergonomic risks, largely due to toolbox talks and safety training. However, the most frequently encountered ergonomic risk factors were repetitive and awkward postures, extreme temperatures, high task repetition, and contract stress. These risks contributed to widespread musculoskeletal pain, particularly in the lower back, shoulders, and upper back, with bricklayers reporting the highest incidence of body pain. Health and safety management practices on construction sites were generally strong. All respondents were provided with personal protective equipment (PPE), received safety training, and reported that accidents were formally documented. Employers were found to implement preventive measures such as adherence to OSHA guidelines, safety meetings, equipment maintenance, and workspace housekeeping.

In relation to Industrial Revolution 4.0 (IR 4.0), awareness among workers was limited, with just under half recognizing the term and only basic familiarity with related technologies such as IoT and sensors. Key challenges to IR 4.0 implementation included unclear benefits, training requirements, resistance to change, and cost concerns. Despite this, respondents acknowledged potential benefits, particularly in raising productivity and standards, modernising the industry, improving site safety, reducing risks, and enhancing sustainability.

Besides, this chapter develop the framework of ergonomic risk among the trades at the construction site. This framework comprises four key elements: site issues and accidents, ergonomic risk factors, effects of ergonomic risks, and prevention or improvement strategies. Ergonomic risks such as forceful exertion, repetitive tasks, awkward postures, and environmental factors can lead to work-related musculoskeletal disorders, reduced productivity, increased costs, and project delays. Preventive measures, including safety training, use of personal protective equipment, incentive programs, and adoption of Construction 4.0 technologies, are emphasized to mitigate these risks. Overall, the framework highlights how effective ergonomic risk management can improve safety performance, productivity, worker well-being, and sustainability in the construction industry.

Finally, the validation survey was conducted among 8 construction professionals in construction industry to solicit feedbacks on the three items (i.e., 1) rate the completeness of the framework; 2) rate the appropriateness of the framework regrading to the related issue; and 3) rate the framework in terms of ease of understanding of the framework, the ease of use, and beneficial use of the framework).

The validation findings indicate that the framework is appropriate for impleme ntation and execution by professionals and authorities (i.e., government agencies, cont ractors, and consultants) on construction sites. The following chapter, Chapter 5, provides the conclusion and recommendations for further research.

# CHAPTER 5
# CONCLUSION

## 5.1 Conclusion

The aim of this research was to propose Framework of Ergonomic Risk Factor Among the Trades at construction in Malaysia. Whilst the first objective is to identify Ergonomic Risk Factors at Construction Site. Second objective is to investigate Effects of Ergonomic Risk Factors toward Trades at Construction Site and Lastly, third objective is to Propose Framework of Ergonomic Risk Factor at Construction Site.

***Objective 1: Investigate Ergonomic Risk Factors among Trades at Construction Site***

This study established that Repetition or Awkward is the majority of Ergonomic Risk having by the trades with Rank 1 and mean 4.67 (0.471). Follows with Extreme Temperature with mean 3.91 (1.352) and the Rank is 2. While Rank 3 is High Task Repetition and the mean is 3.86 (1.310). Next Rank is 4, Contract Stress with mean 3.60 (0.805). Then Rank 5 and 6 are Forceful Exertation and Vibration. Both risks are with mean 3.51 (1.201) and 1.96 (1.354).

In addition, findings from the document analysis of occupational injury statistics, SHASSIC/QLASSIC standards, the Construction 4.0 Strategic Plan, Rancangan Malaysia, the National Construction Policy 2030, and the Sustainable Development Goals (SDGs) highlight an increasing trend in occupational injuries, particularly musculoskeletal and upper limb disorders, underscoring the need for stronger ergonomic interventions. Thus, Objective for this research successfully achieved.

***Objective 2: Identify the Effects of Ergonomic Risk Factors on Workers in Selected Construction Trades***

This study indicated that majority of masonry or bricklayer with frequency 16 having body pain in last 6 months. Follow by concreting, roofing, electrician, barbender and plumber with frequency 8. While general workers are 6 frequencies. However, painting or plastering with 8 frequencies do not having body pain in last 6 months. In addition, Lower Back is the most affected body part with mean 4.00 (1.212) with Rank

1. While Rank 2 is shoulder and the mean is 3.89 (0.827). Follows by Rank 3, Upper Back with mean 3.68 (1.300). While Rank 4 and 5 are Ankles or Feet and Wrist or Hand with mean 3.53 (0.927) and 3.51 (1.079). Knees and Hips or Thigh both are with Rank 6 and 7 and mean 3.35 (1.045) and 3.03 (1.242). Subsequently follows by Rank 8 and 9 and they are Elbow and Neck. Both with mean 3.00 (1.125) and 2.99 (1.278).

Furthermore, the literature review presented in Chapter 2 comprehensively explains the effects of ergonomic risks and forms the basis for the development of the conceptual framework. Therefore, Objective 2 has been successfully achieved.

***Objective 3: Determine Improvement measure for Reducing Risk Factor at Construction Site***

The study revealed that Induction and, briefing on site or training when started work is Rank 1 with mean 4.05 (0.870). Respondent also agreed that workers need to be inducted on site Rank 2 and the mean is 4.04 (0.863). Employer also need put in place safety and health measure in work site is Rank 3 with mean 3.96 (0.834). Meanwhile, Industrial Revolution 4.0 also part of initiative. benefits from implementing of Industrial Revolution IR 4.0 in construction site. Raising standards and productivity is Rank 1 and the mean is 3.26 (0.443). Rank 2 is Modernising the industry with mean 3.25 (0.436). Followed by Improving site safety which is Rank 3 and mean is 3.24 (0.428). Next Rank is number 4 Reducing Risk with mean 3.14 (0.347). Finally, but not least is Rank 5. They are Saving time and money and also Improving sustainability with mean 3.03 (0.157).

Objective 3 was effectively addressed through the findings presented in Chapter 2 (Literature Review). Accordingly, Objective 3 has been successfully achieved.

***Objective 4: Develop Framework for Managing Ergonomic Risk Factor at Construction Site***

This study explained framework with activity related of the trades, will lead to the ergonomic risk which is affected their body and resulting in effect of ergonomic in construction site as well. Thus, ergonomic prevention can be identified from there and one of them is by Industrial Revolution 4.0. Apart from the Ergonomic Risk then results and outcome will appear. Diagram can be found in previous Chapter 4. Thus, Objective 4 was successfully achieved.

## 5.2 Recommendation

According to the study's conclusions, all workers should get frequent ergonomic risk factor training, as well as work-related musculoskeletal disorders. This should be done on a regular basis by trained, DOSHS-licensed experts. The training should cover all aspects of construction safety and health.

The study further recommends:

i. Employers/owners of construction sites should take a proactive role in regulating safety and health initiatives on their sites.
ii. Employers/owners of construction should implement programme on ergonomic awareness among their workers.
iii. Employers/owners of construction should include more information on construction 4.0 in their safety and health programme.

Further, the framework of ergonomic risk among the trades at construction site in the research is expected to be used as a guideline for stakeholders (i.e., contractors, consultant, and authorities) involved in construction project in Malaysia. However, the framework has not been extensively tested on live projects. Hence, for further research, three recommendations are suggested.

I. To apply and evaluate the framework on projects to confirm its validity and support further utilization.
II. Suggested that research can be conducted at construction site located outside state of Selangor to ensure broader and more representative results.
III. To include ergonomic awareness among the trades at construction site in the framework.

## 5.3 Limitation

Despite achieving the objectives of this research, several limitations should be acknowledged.

I. This study was limited to selected construction sites in Malaysia. Therefore, the findings may not be fully representative of all construction projects nationwide, particularly those involving different scales of projects,

geographical locations, or work practices. As such, the generalisation of the results should be interpreted with caution study apply and evaluate the framework on projects to confirm its validity and support further utilization.

II. The study focused mainly on common ergonomic risk factors and body discomfort among construction trades without conducting direct ergonomic measurements or observational assessments, such as posture analysis, biomechanical evaluation, or on-site ergonomic tools. This may limit the precision of identifying the actual level of ergonomic risk exposure.

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# APPENDICES

# APPENDIX 1

## Exploratory Interview for the Framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia.




**COLLEGE OF BUILT ENVIRONMENT**

MASTER OF SCIENCE BUILT ENVIRONMENT (AP 781)

Dear respondents,

I am Naela Udani Binti Suainbon (UiTM student ID No. 2021395325) from AP 781, UiTM Shah Alam. Currently, I am pursuing Master of Science Built Environment. The title of my research is "**The Framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia**" with the objectives of:

I. To Identify Ergonomic Risk at Construction Site
II. To Investigate Effects of Ergonomic Risk Towards Trades at Construction Site.
III. To Investigate Improvement of Ergonomic Risk Factor in Construction Site
IV. To Develop a Framework of Ergonomic Risk at Construction Site.

Therefore, I would appreciate if you could spend a few minutes of your time to complete this questionnaire. The results from this semi structured interview will be used for research purpose only and anonymousity of respondents will be our priority. There is no right or wrong answer as I am seeking your opinion only. I appreciate your assistance since the success of this research depends upon your response. All responses to this interview question will be treated with the utmost confidential.

Thank you.

Researcher

(Naela Udani Binti Suainbon)

Email: naelasuainbon@yahoo.co.uk

1 Why is health and safety important on a construction site?

2 What type of injuries have you encountered or heard of?

3 How do you define Ergonomics?

4 What are common ergonomic problems you have encountered or identified during a project?

5 In your opinion, who should be responsible for mitigating ergonomic risk factors?

6 Have you implemented ergonomic principles in your designs?

7 What courses have you attended with regards to Ergonomics?

8 Do you feel formal training on ergonomic principles is important?

9 Have you ever come across term IR 4.0 ?

10 What are the challenge facing and benefit IR 4.0?

THANK YOU

# APPENDIX 2

## Questionnaire Survey for the Framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia.




**COLLEGE OF BUILT ENVIRONMENT**

MASTER OF SCIENCE BUILT ENVIRONMENT (AP 781)

Dear respondents,

I am Naela Udani Binti Suainbon (UiTM student ID No. 2021395325) from AP 781, UiTM Shah Alam. Currently, I am pursuing Master of Science Built Environment. The title of my research is **"The Framework of Ergonomic Risk Factor Among the Trades at Construction Site in Malaysia"** with the objectives of:

I. To Identify Ergonomic Risk Factors at Construction Site
II. To Investigate Effects of Ergonomic Risk Factor Towards Trades at Construction Site.
III. To Propose a Framework of Ergonomic Risk Factor at Construction Site.

Therefore, I would appreciate if you could spend a few minutes of your time to complete this questionnaire. The results from this questionnaire will be used for research purpose only and anonymousity of respondents will be our priority. There is no right or wrong answer as I am seeking your opinion only. I appreciate your assistance since the success of this research depends upon your response. All responses to this questionnaire will be treated with the utmost confidential.

Thank you.

Researcher

(Naela Udani Binti Suainbon)
Email: naelasuainbon@yahoo.co.uk

√ Kindly tick your preference choices
Fill in your answers in space provided

**A. Personal Information of the respondent**

1) What is your gender?

☐ Male ☐ Female

2) What is your age?

☐ 19-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60 and above

3) What is your job description?

☐ Unskilled casual worker

☐ Skilled casual worker

☐ Others. Please state your answer :

4) How many years have you been works in construction industry?

☐ Less than 3 years ☐ 3-8 years ☐ 9-14 years ☐ 15-20 years ☐ 21 years and above

5) What is/are your daily work?

☐ Masonry / Bricklayer

☐ Concreting

☐ Roofing

☐ Painting / Plastering

6) Do you find your daily work activities strenuous? If yes, why?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Heavy lifting | ☐ | ☐ | ☐ | ☐ | ☐ |
| Sliding | ☐ | ☐ | ☐ | ☐ | ☐ |
| Rotation sometimes | ☐ | ☐ | ☐ | ☐ | ☐ |

7) How many hours do you work in a day?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 4 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| More than 12 hours | ☐ | ☐ | ☐ | ☐ | ☐ |

8) Do you take breaks during your working hours?

☐ Yes ☐ No

9) If Yes in question 8 above, for how long?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 1 Hour | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4 Hours | ☐ | ☐ | ☐ | ☐ | ☐ |
| More than 4 hours | ☐ | ☐ | ☐ | ☐ | ☐ |

**B. Ergonomic Risk Factors**

10) Do you understand what ergonomic risk factors are?

☐ Yes ☐ No

11) If YES in question 10 above, do you encounter any of these listed ergonomic risk factors during your daily work activities?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Repetition / Awkward posture | ☐ | ☐ | ☐ | ☐ | ☐ |
| Contract Stress | ☐ | ☐ | ☐ | ☐ | ☐ |
| Forceful exertion | ☐ | ☐ | ☐ | ☐ | ☐ |
| High Task Repetiton | ☐ | ☐ | ☐ | ☐ | ☐ |
| Vibration | ☐ | ☐ | ☐ | ☐ | ☐ |
| Extreme Temperature | ☐ | ☐ | ☐ | ☐ | ☐ |

12) How well can you rate these risk factors on least affected and most affected?

| | Least Affected | Somewhat Affected | Neutral | Affected | Most Affected |
|---|---|---|---|---|---|
| Repetition / Awkward posture | ☐ | ☐ | ☐ | ☐ | ☐ |
| Contract Stress | ☐ | ☐ | ☐ | ☐ | ☐ |
| Forceful exertion | ☐ | ☐ | ☐ | ☐ | ☐ |
| High Task Repetiton | ☐ | ☐ | ☐ | ☐ | ☐ |
| Vibration | ☐ | ☐ | ☐ | ☐ | ☐ |
| Extreme Temperature | ☐ | ☐ | ☐ | ☐ | ☐ |

13) Are PPE necessary during performing work?

☐ Yes ☐ No

14) Are you provided with personal protective equipment (PPE)?

☐ Yes ☐ No

15) What are the PPE provided?

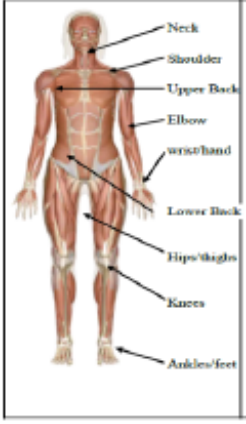
☐ Safety Helmet
☐ Safety Vest
☐ Safety Shoes
☐ Safety Harness
☐ Others. Please state your answer :

**C. Effects of Ergonomic Risk Factors**

16) Have you experienced body pains in the last 6 months?

☐ Yes ☐ No

17) If YES in question 16 above, use the diagram below to indicate the most affected body parts.




| | Very rarely | Rarely | Occasionally | Frequently | Very Frequently |
|---|---|---|---|---|---|
| Neck | ☐ | ☐ | ☐ | ☐ | ☐ |
| Shoulder | ☐ | ☐ | ☐ | ☐ | ☐ |
| Upper Back | ☐ | ☐ | ☐ | ☐ | ☐ |
| Elbow | ☐ | ☐ | ☐ | ☐ | ☐ |
| wrist/hand | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lower Back | ☐ | ☐ | ☐ | ☐ | ☐ |
| Hips/thighs | ☐ | ☐ | ☐ | ☐ | ☐ |
| Knees | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ankles/feet | ☐ | ☐ | ☐ | ☐ | ☐ |

18) How often do you experience the above body pain?

| Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**D. Health and Safety Management**

19) Are accidents and incidents reported in work sites? ☐ Yes ☐ No

20) If YES in question 22 above, to whom do you report it to? ☐ Foreman ☐ Workmate ☐ Supervisor ☐ Doctor/Nurse ☐ DOSH Office ☐ Others. Please state your answer :

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 21) Do you know what Occupational Safety & Health Act 2007 is? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22) Do you think employers MUST put in place safety and health measures in work site? | | | | | |
| 23) Was there an induction/brief/training when you started work at construction sites | ☐ | ☐ | ☐ | ☐ | ☐ |

24) Do you think workers need to be inducted or trained?

25) Do you think your employer has put measures to prevent accidents/incidents at your work site? ☐ Yes ☐ No

26) If YES in question 25 above, what are these measures?

- ☐ Follow OSHA guideline and report any dangerous working condition
- ☐ Provide Safety Training for all employee
- ☐ Hold frequent crew safety meetings
- ☐ Utilize protective clothing and gear
- ☐ Maintain the equipment and tools
- ☐ Keep the workspace clean
- ☐ Others. Please state your answer :

27) Is there anything that can be done to make your workplace safe? If YES, please explain

.....

.....

**E. Industry Revolution 4.0 (IR 4.0)**

28) Have you ever come across about the term IR 4.0?

☐ Yes ☐ No

29) How did you know about IR 4.0?

☐ Induction / Training

☐ Seminar

☐ Online advertisement

☐ Others. Please mention the sources :

30) Have you ever heard about the following terminalogies?

| | Yes | No |
|---|---|---|
| Sensor | ☐ | ☐ |
| Simulation | ☐ | ☐ |
| Additive Manufacturing | ☐ | ☐ |
| Autonomous Robots | ☐ | ☐ |
| System Integration | ☐ | ☐ |
| Building Information Modelling (BIM) | ☐ | ☐ |
| Augmented Reality | ☐ | ☐ |
| Cloud Computing | ☐ | ☐ |
| Big Data | ☐ | ☐ |
| Internet of Thing (IOT) | ☐ | ☐ |

31) Have you ever attended any event or training focusing on IR 4.0?

☐ Yes ☐ No

32) What are the challenges facing industry 4.0 ?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Resistance to change | ☐ | ☐ | ☐ | ☐ | ☐ |
| Unclear benefit and gain | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lack of standardization | ☐ | ☐ | ☐ | ☐ | ☐ |
| Cost of Implementing | ☐ | ☐ | ☐ | ☐ | ☐ |
| Impact on workers | ☐ | ☐ | ☐ | ☐ | ☐ |
| Training requirement | ☐ | ☐ | ☐ | ☐ | ☐ |

33) What are the benefits IR 4.0?

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Saving time and money | ☐ | ☐ | ☐ | ☐ | ☐ |
| Raising standards and productivity | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improving sustainability | ☐ | ☐ | ☐ | ☐ | ☐ |
| Modernising the industry | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improving site safety | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reducing risk | ☐ | ☐ | ☐ | ☐ | ☐ |

**THANK YOU**

# APPENDIX 3

## Validation Questionnaire for the Framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia.

**Validation Questionnaire**



UNIVERSITI TEKNOLOGI MARA,
40450 SHAH ALAM

**VALIDATION FEEDBACK FORM**

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**A FRAMEWORK OF ERGONOMIC RISK AMONG THE TRADES AT CONSTRUCTION SITES IN MALAYSIA**

**Background:**

Working conditions in the construction sector are highly accident-prone, with numerous ergonomic risks involved. Tradespeople are exposed to significant amounts of various hazards that could lead to bodily harm or even death. They also encounter a wide range of safety and health risks on site, including repetitive or awkward postures, thermal stress, loud noise, vibrations, and more. The greater the exposure to these risks either individually or in combination the higher the likelihood of ergonomic harm or the development of Work-related Musculoskeletal Disorders (WMSDs). The objectives of this study are to identify ergonomic risks and investigate the effects of these risks towards workers. For that, quantitative method by means of questionnaire was adopted for data collection with tradesperson from selected residential projects. The findings indicated that repetition or awkward postures, high task repetition, and extreme temperatures are three major ergonomic risks faced by tradesperson. As a result, the lower back, shoulders, upper back, and wrists or hands are the most affected body parts, often leading to pain and discomfort among workers. This finding is hoped to assist in improving necessary safety procedures and work regulation in workspace.

1. **Exploratory semi-structured interviews** with 8 Professionals from construction organizations to provide their understanding on ergonomic risk, based on their experience in construction site,
2. **Questionnaire survey** distributed to 80 respondents (trades) gather quantitative data on ergonomic risk in the construction site,
3. **Document analysis** examining the related document of ergonomic risk in construction site at Malaysia
4. **Development of a Framework** tailored specifically for construction site, based on insights gathered from the above research phases.

**Purpose:**

The purpose of this framework is to ensure workers have the necessary safety procedures and regulation in workplace. Also, able to control or eliminate risk , the consequences and/or likelihood of illness, injury and death are reduced. Lastly, to provide additional data to CIDB and OSHA for eliminate ergonomic risk.

**Element of the Ergonomic Risk:**

The framework has 4 elements ( E ), Input ( I ) and Output/Outcome ( O ):

E1: Focus on the issue or accidents occurred on site. This element also highlight the dangerous condition of site including hazards.

E2/I: This Element highlights ergonomic risk among the trades on site. Consist of ergonomic risk and trades involve.

E3: This Element deals with effect of ergonomic risk among the trades on site and effect to construction industry.

E4: Improvement and prevention strategies are applied to the ergonomic risks determined in this element.

O: output of this research framework is identified.

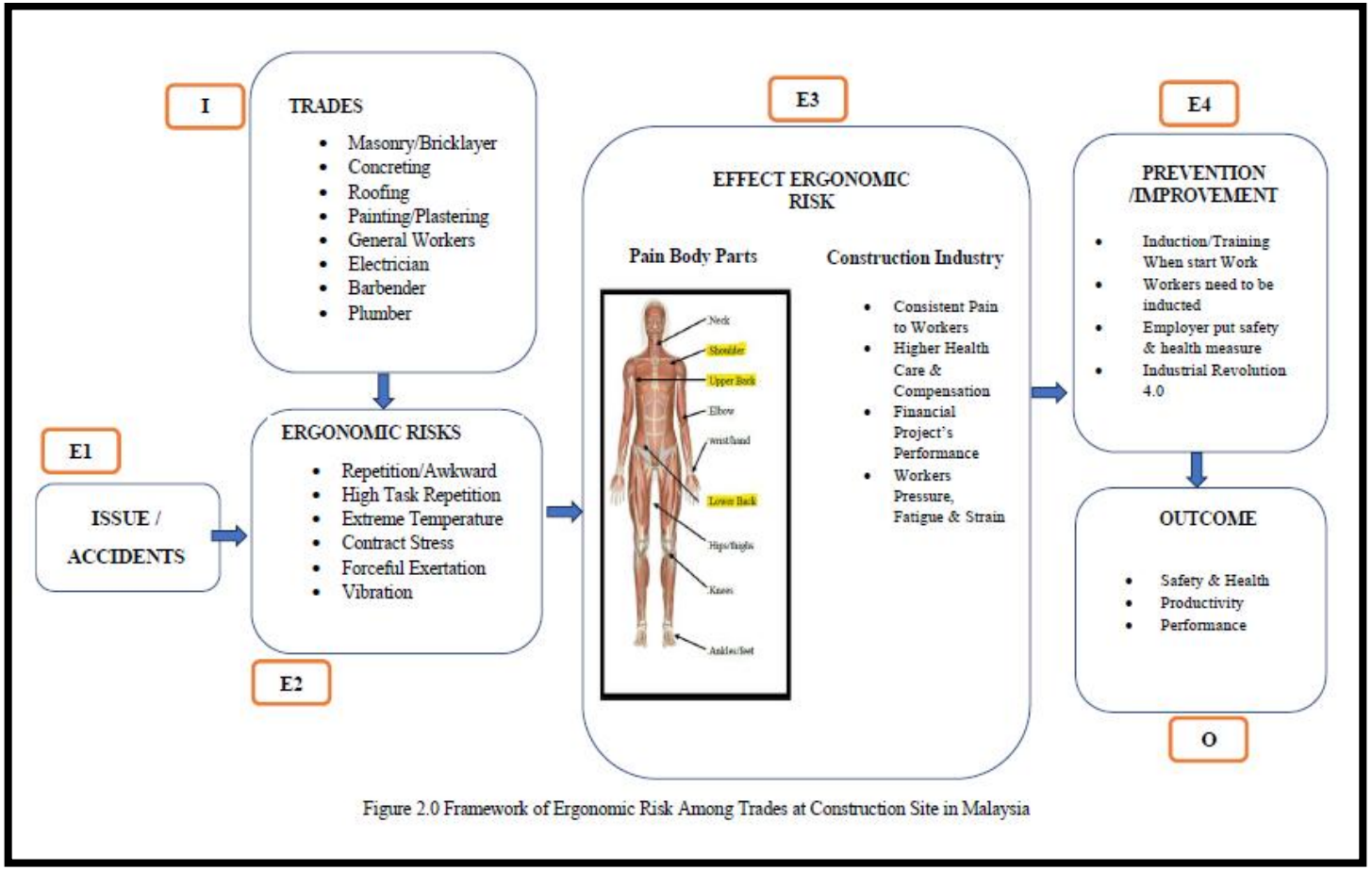



Figure 2.0 Framework of Ergonomic Risk Among Trades at Construction Site in Malaysia

Figure 2, shows the conceptual framework in this research. Based on the results of the finding between questionnaire and the preliminary study, framework of ergonomic risk among the trades at construction site in Malaysia is develops. The framework comprises of Input ( I ), four elements ( E ) and Output ( O ) . Element 1 ( E1 ) focus on the issue or accidents occurred on site. Element 2 ( E2 ) consists of Ergonomic Risk that happened among the trades which is Input ( I ) to the E2. Whilst Element 3 ( E3 ) indicate effect of ergonomic risk. Then Element 4 ( E4 ) emphasis on prevention or improvement of ergonomic risk. Lastly, Output ( O ), refers to the outcomes or output of the research.

*Element 1 ( E1 ): Issue / Accidents*

Element 1 (E1), focus on the issue or accidents occurred on site. Abas et al (2020) stated that Major construction projects in Malaysia are exposed to dangerous conditions which can cause accidents and consequently affect the safety performance of the construction projects. The causes of accidents in construction industry are related to unique nature of the industry, human behavior, improper site conditions, unsafe work method, equipment and procedures which affected from poor safety management. These causes could result in accidents which further cause disruption of work and decrease the work rate. Vijayakumar and Choi (2022) explained that building workers are exposed to excessive construction site dangers that can result in injuries or even death. They face different kinds of safety and health hazards whilst working in their work sites every day.

*Element 2 ( E2 ) / Input ( I ): Ergonomic Risk among the Trades*

Element 2 ( E2 ) consists of Ergonomic Risk that happened among the trades which is Input ( I ) to the E2. The three major ergonomic risk factors are force (how much you lift/push/pull), repetition (how frequently you conduct the operation), and posture (body position). Other ergonomic risk concerns include vibration, contact stress, prolonged exertion, and frigid temperatures (Lop, Mat Salleh, Yop Zain & Saidin, 2019). Anagha and Annie (2020) in their studies also agreed that the main ergonomics risk factors were uncomfortable posture, repetitive movements, and vibration. Other ergonomic risks include unpleasant static positions, muscle and tendon contact, and severe temperatures.

*Element 3 ( E3 ) : Effect of Ergonomic Risk*

Element 3 ( E3 ) indicate effect of ergonomic risk. In addition, ergonomic risks on construction sites can result in severe and traumatic joint and muscle injuries. Exposure to a single risk factor or a combination of risk variables increases the possibility of ergonomic injury or illness, commonly known as Work Related Musculoskeletal Disorders (WMSD). They can lead to long-term and serious medical issues that prevent individuals from working and enjoying life (Francis & Deepan, 2019). Typically, workers in the construction industry suffer from MSD but are unaware that they having it (Lop, Mat Salleh, Yop Zain & Saidin, 2019).

Work-related musculoskeletal injuries and disorders (WMSDs) are among the most frequently reported causes of lost or restricted work time in the construction industry. Overexertion, sprains, strains, pulls, and/or tears are all an unfortunate regular occurrence on many constructions job sites (Sneller , Ahn & Choi, 2019). According to Santarelli (2023) ergonomic hazards can cause consistent pain to workers, who often choose to work through that pain. According to OSHA, "working hurt" is among the largest problems facing construction workers today, as working hurt can not only lower productivity, but can cause lifelong pain and disability.

Workers in the construction industry are around 50% more likely to develop WMSDs. As a result, the construction industry frequently engages in higher medical expenses and compensation costs for injured workers (Dong, Betit, Dale, Barlet & Wei, 2019). To some extent, construction workers are involved with challenging tasks. Due to the construction and building industries' adaptability, diversity, and dynamic nature. Workers in the construction industry are at risk of limitations, injuries, illness, and even death due to the broad scope of their work and the complexity of the projects. Construction is one of the seven jobs with the highest incidence rates. Work-related musculoskeletal diseases (WRMSDs) affect a substantial number of employees, resulting in substantial financial losses. (Katode M, Lokhande H, Kocharekar S & Jadhav A, 2021).

Accidents that occur on a construction site may create a delay in the completion of the project, which is connected to the time factor in project performance. Besides, the accident had an influence on project performance in terms of indirect workplace expenses to the company

and workers. This is due to an increasing in expenditures, which has a financial effect on the project's performance (Abdul Aziz, Mohd Nordin, Ismail & Yunus, 2020). Every construction worker is likely to be temporarily unable to work as a result of relatively significant injuries or health problems sustained while working on a building site at some point. This can gradually put pressure on workers to raise their output, which opens the door for shortcuts to be taken instead of following safe work procedures that are also designed prior to the start of work (Sneller, Choi, Ahn & Choi, 2019).

*Element 4( E4 ) : Prevention/Improvement of Ergonomic Risk*

Then Element 4 ( E4 ) emphasis on prevention or improvement of ergonomic risk. Albarkani & Shafii (2021) observed that staff training is a work activity that can make a very significant contribution to the overall effectiveness and profitability of an organization. He, therefore, provides a systematic approach to training which encases the main elements of training. After the training program, an evaluation is carried out to ascertain the effectiveness of the "program in line with the need'' which had been identified.

One of the suggested strategies is to incorporate incentive programs into construction projects. Safety incentive programs refer to programs that reward workers for achieving certain goals related to workplace safety (Abas et al., 2020). Some studies show that safety incentive programs can improve many safety performances at the construction site. This is an initiative that rewards employees for improving their safety procedures and decreasing the number of reported injuries and incidents (Abas et al., 2020).

Other than that, Personal Protective Equipment (PPE) is equipment worn to minimize exposure to serious workplace injuries and illnesses. The PPE is also worn to reduce exposure to ergonomics-related risk factors. These injuries and illness may come from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Example of PPE equipment are such as gloves, safety glass, shoes, earplugs, hard hats, respirators, vests and full body suits. The example of the uses of PPE in workplace are such using padding to reduce direct contact with hard, sharp, or vibrating surfaces and wearing good fitting thermal gloves to help with cold conditions while maintaining the ability to grasp items easily (Ghazali et al., 2022).

Additionally, Industry 4.0 was initiated to explore how the manufacturing industry could benefit from the integration and implementation of new technologies. The concept is broad and considers many aspects of interdisciplinary technologies and collaborations, which

is imperative to achieve continuous automation through different processes (Schönbeck, Löfsjögård & Ansell, 2020). Besides, Construction 4.0 also increased the productivity. Industry 4.0 promises increase in productivity through the integration of digital systems of production with analysis and communication of all data generated within an intelligent environment (Alalout et.al, 2020). Certainly, implementing Construction 4.0 can provide a slew of advantages with the internet of things as discussed before. Worker only need to manage the tools and machine that he will be used. Eventually, will decrease hazard on workers. A well-established culture of accident prevention can be developed with help of Industry 4.0 implementation (Aslan, 2019).

*Output/Outcomes ( O ) : outcomes or output of the research.*

Output ( O ), refers to the outcomes or output of the research. As a last perspective, several elements have been identified that can impact the safety performance of the construction site. Implementing these safety elements has a variety of benefits, including reducing the frequency of accidents on the construction site, increasing productivity, completing the project on time, lowering compensation costs, and improving employee morale. Good project-level safety performance can lead to improved safety performance in the construction sector. Additional, Construction 4.0 also brings a lot of benefit.

**Validation questionnaire:**

As part of the validation process, we request your comments on the usefulness of the framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia. Please provide your views (by entering tick (√) on the five-point Likert Scale, (1 denotes 'Poor and 5 denotes Excellent) based on the following questions:

| *How do you rate the completeness of the framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia:* | | **Please indicate your level of opinion by a tick (√) per row** | | | | |
|---|---|---|---|---|---|---|
| | | **Poor** | **Satisfactory** | **Good** | **Very good** | **Excellent** |
| | | **1** | **2** | **3** | **4** | **5** |
| 1 | **Issue/Accidents in construction sites (E1)** | | | | | |
| **Please state the reasons:** | | | | | | |
| 2 | **Ergonomic Risk among the trades, Effect & Improvement of Ergonomic Risk (E2, I, E3 & E4)** | | | | | |
| **Please state the reasons:** | | | | | | |
| 3 | **Outcomes of Research Framework (O)** | | | | | |
| **Please state the reasons:** | | | | | | |
| *How do you rate the appropriateness of the framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia.* | | **Poor** | **Satisfactory** | **Good** | **Very good** | **Excellent** |
| 1 | **Issue/Accidents in construction sites (E1)** | | | | | |
| **Please state the reasons:** | | | | | | |
| 2 | **Ergonomic Risk among the trades, Effect & Improvement of Ergonomic Risk (E2, I, E3 & E4)** | | | | | |
| **Please state the reasons:** | | | | | | |
| 3 | **Outcomes of Research Framework (O)** | | | | | |
| **Please state the reasons:** | | | | | | |

| | *How do you rate the framework of Ergonomic Risk Among the Trades at Construction Site in Malaysia in term of:* | Poor | Satisfactory | Good | Very good | Excellent |
|---|---|---|---|---|---|---|
| | **Ease understanding of the framework** | | | | | |
| | **Please state the reasons:** | | | | | |
| | **Ease use of the framework** | | | | | |
| | **Please state the reasons:** | | | | | |
| | **Beneficial use of the framework to contractors/consultants/authorities** | | | | | |
| | **Please state the reasons:** | | | | | |

**2. Please provide additional comments or suggestions on the applicability of the framework**

| |
|---|
| |

All information will be treated as confidential and used solely for this research. We would appreciate if you could provide the following information:

**Name:**…….

**Position:**……

**Experience**.....**years**

**Name of organisation:**…….

*End of Questionnaire*
*Thank you very much for your cooperation and help.*

# AUTHOR'S PROFILE



Naela Udani Binti Suainbon obtained Bachelor of Quantity Surveying (Hons) in 2014 from Universiti Teknologi Mara (UiTM) Seri Iskandar, Perak. Her Master Thesis Involve Ergonomic Risk Among Trades at Construction Sites in Malaysia.

## LIST OF PUBLICATIONS

Naela Udani Suainbon, Rumaizah Mohd Nordin & Rostam Yaman (2024). Ergonomic Risk Among Trades at Construction Sites in Malaysia, p. 1-10