DESIGN MANUFACTURING INTERFACE: FEASIBILITY STUDY ON ASSEMBLY PROCESS TIME ESTIMATION (TIME STUDY) AND ERGONOMIC OF KESIDANG CNC 3D ROUTER)

MUHAMMAD ANIQ NAJMI BIN AZIZI

B092010011

BACHELOR OF TECHNOLOGY ENGINEERING IN MANUFACTURING (HONS)

2024

Faculty of Technology and Industrial and Manufacturing Engineering

DESIGN MANUFACTURING INTERFACE: FEASIBILITY STUDY ON ASSEMBLY PROCESS TIME ESTIMATION (TIME STUDY) AND ERGONOMIC OF KESIDANG CNC 3D ROUTER)

Muhammad Aniq Najmi Bin Azizi

Bachelor Of Manufacturing Engineering Technology With Honours

2024

DESIGN MANUFACTURING INTERFACE: FEASIBILITY STUDY ON ASSEMBLY PROCESS TIME ESTIMATION (TIME STUDY) AND ERGONOMIC OF KESIDANG CNC 3D ROUTER)

MUHAMMAD ANIQ NAJMI BIN AZIZI

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor Of Manufacturing Engineering Technology With Honours

Faculty of Technology and Industrial and Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this Choose an item. entitled "**DESIGN MANUFACTURING INTERFACE: FEASIBILITY STUDY ON ASSEMBLY PROCESS TIME ESTIMATION (TIME STUDY) AND ERGONOMIC OF KESIDANG CNC 3D ROUTER)** " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *Muhammad Aniq Najmi Bin Azizi*

Date : 10 January 2024

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (FTKIP) with Honours.

Signature	:	
Supervisor Name	:	*Dr Hambali Bin Boejang*
Date	:	10 January 2024

DEDICATION

My family was the focus of my dissertation work. En Azizi Mahmood and Pn Azura Hussin, my devoted parents, who offered me support not only financially but also morally and physically, deserve a particular word of thanks for their words of inspiration and push for persistence. my thesis is also dedicated to my wonderful friends and fellow researchers who have helped me out and supported me during my research journey. I am incredibly grateful for their time and work in helping me.

I vowed to make my family proud by completing these enormous academic objectives, and I believe I have done just that. On my graduation, I wish to be able to enjoy my accomplishments.

ABSTRACT

The production of new products that have not yet been researched on how the machine is produced according to assembly methods suitable for humans is investigated in this thesis. This study aims to see the production of this KESIDANG machine can be highlighted in the scope of learning in the future which aims to study the manpower ergonomics of the CNC 3D router KESIDANG. The study about KESIDANG that relate to the new product development (NPD) process, concurrent engineering (CE), and design manufacturing interface (DMI) is unknown. This explorative research is done to investigate the effect of new product development (NPD) process, concurrent engineering (CE), and design manufacturing interface (DMI) on the new machine of KESIDANG CNC 3D Router. Based on the literature review reading, research about the NPD, CE and DMI that can relate toward the KESIDANG were established. The study of ergonomic that consist of anthropometry and rapid upper limb assessment (RULA). This is called quantitative data. The RULA use to collect the data of human body posture when make installation KESIDANG. Score level of MSD risk use to analysis the data collected in RULA. Analysis is explained about the risk that human will be borne when installing the machine. CATIA software will be used to analyze the data of human body posture. Data collection of human body posture concurrent with time taken. Stopwatch will be used when assembly activities to record the assembly time. The assembly line of KESIDANG machine covering of frame, x-axis, y-axis, and z-axis. In conclusion, all objectives have been achieved, and it can be concluded that worker ergonomic and time study is crucial in assembly of KESIDANG

ABSTRAK

Penghasilan produk baru yang masih belum diteliti bagaimana mesin dihasilkan mengikut kaedah pemasangan yang sesuai untuk manusia disiasat dalam tesis ini. Kajian ini bertujuan untuk melihat penghasilan mesin KESIDANG ini dapat diketengahkan dalam skop pembelajaran pada masa hadapan yang bertujuan untuk mengkaji ergonomik tenaga kerja penghala CNC 3D KESIDANG. Kajian tentang KESIDANG yang berkaitan dengan proses pembangunan produk baharu (NPD), kejuruteraan serentak (CE), dan antara muka pembuatan reka bentuk (DMI) tidak diketahui. Penyelidikan penerokaan ini dilakukan untuk menyiasat kesan proses pembangunan produk baharu (NPD), kejuruteraan serentak (CE), dan antara muka pembuatan reka bentuk (DMI) ke atas mesin baharu Penghala 3D CNC KESIDANG. Berdasarkan pembacaan tinjauan literatur, penyelidikan mengenai NPD, CE dan DMI yang boleh dikaitkan dengan KESIDANG telah diwujudkan. Kajian ergonomik yang terdiri daripada antropometri dan penilaian anggota atas pantas (RULA). Ini dipanggil data kuantitatif. RULA digunakan untuk mengumpul data postur badan manusia semasa membuat pemasangan KESIDANG. Tahap skor penggunaan risiko MSD untuk menganalisis data yang dikumpul dalam RULA. Analisis diterangkan tentang risiko yang akan ditanggung oleh manusia apabila memasang mesin. Perisian Osmond Ergonomic akan digunakan untuk menganalisis data postur badan manusia. Pengumpulan data postur badan manusia serentak dengan masa yang diambil. Jam randik akan digunakan apabila aktiviti perhimpunan untuk merekod masa perhimpunan. Barisan pemasangan mesin KESIDANG meliputi bingkai, paksi-x, paksi-y dan paksi-z. Kesimpulannya, semua objektif telah dicapai, dan dapat disimpulkan bahawa ergonomik dan kajian masa pekerja adalah penting dalam pemasangan KESIDANG.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. In order to complete this task, I would want to appreciate and express my sincere gratitude to my supervisor, Dr. Hambali bin Boejang. I was able to complete my thesis under his direction and counsel. His unwavering tolerance for guiding and offering priceless insights will always be cherished. I also like to thank the intern students that supported my thesis writing. I want to express my gratitude to my friends for supporting me through all of the challenges this semester.

I want to express my sincere gratitude to my family in particular for their unwavering assistance and patience as I conducted my research and wrote my thesis. Your supplications for me have kept me going so far. It's possible that this research would not have been possible without their moral backing.

Finally, I would want to express my gratitude to everyone who helped me start my UTEM studies and inspired me to do so.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

CNC	-	computer numerical control
NPD	-	new product development
RULA	-	Rapid Upper Limb Assessment
MSD	-	Muscular disorder
PD	-	product development
CAD	-	computer-aided design
CAM	-	computer-aided manufacturing
CAE	-	Computer aided engineering
CE	-	Concurrent engineering
QFD	-	Quality function deployment
FEA	-	Finite element analysis
DFM	-	Design for Manufacture
DFA	-	Design for Assembly
DFMA	-	Design for manufacturing and assembly
FMEA	-	Failure modes and effects analysis
BOM	-	Bill of Materials
MRO	-	maintenance, repair, and overhaul
DPA	-	Design Preliminary Approval
DMI	-	design-manufacturing interface
CT	-	cycle time

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

In this chapter is about discussing the background of new machine that is called KESIDANG CNC 3D Router. The purpose of the study as well as the goals related to the project will be presented in this chapter. The problem statement about existing problems and the objective we must achieve in this project also will be included in this chapter.

1.1 Background

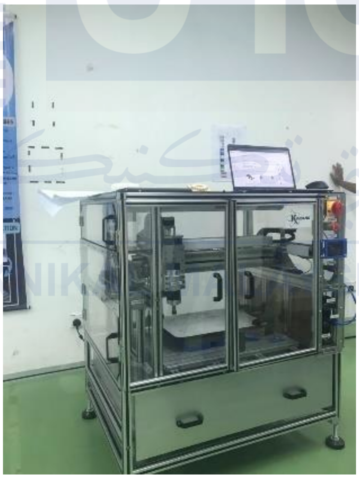


Figure 1.1KESIDANG CNC 3D Router

In December 2021, a programmed called Talent Development Programme: Developing Tomorrow’s Expertise was held for Product Design Student of Faculty of Mechanical & Manufacturing Engineering Technology. As organizer of this programme, Dr. Hambali bin Boejang has proposed a product development project which was to develop a CNC 3D Router Machine in order to share and implement the knowledge that he experienced during his time in automotive industry

KESIDANG is a new machine, and the production of this project requires the labor of 6 UTEM students, the project director and help of several supervisors. KESIDANG CNC 3D Router, computer numerical control (CNC) is the perfect computer-controlled machine for cutting and engraving variety of materials, such as wood, composites, metals, plastics, glass, and foams and others materials. It typically mounted on the spindle of a CNC router is a hand- held router.
The origin of the name of the KESIDANG comes from a machine naming contest. We want everyone to know that we are developing a machine that has potential for teaching and learning purposes. Through a machine naming competition that was participated by 100 participants and after screening we chose KESIDAG as the name of the CNC 3D Router project. KESIDANG is the official flower of UTEM and also the official flower of Melaka. The production target of this CNC 3D Router is to at least reach the stage of producing a functional prototype.

1.2 Problem Statement

The inspired method can be seen to have a significant difference in terms of the design produced different from the existing design. The project of KESIDANG opened the eyes of many parties that this existing machine can be improved in terms of its functionality and a design that is more attractive and comfortable to use. Lack of knowledge about ergonomic posture and time study during installation KESIDANG is most problem we are faced. It is an opportunity to study the application of it.

KESIDANG is a new machine, and the production of this project requires the labor of six UTEM students, the project director and the help of several supervisors. This new project provides an opportunity to go to the next level which is production engineering. No analysis data about the relationship between the appropriate installation method affects the time taken when installation KESIDANG is the issues we encounter.

1.3 Research Objective

Each new machine production has their own production line by doing minimal research in producing their own products. Thus, it is an opportunity to study the application of it. It can see that the main objective is to create a production line for this KESIDANG project. This KESIDANG CNC 3D Router manufacturing project has been produced and developed so that these objectives can be achieved among others:

a) To collect data of time taken & data of human body posture during assembly KESIDANG..

b) To analyze the relationship between the ergonomic installation of KESIDANG affecting the length of time taken for installation to be performed.

1.4 Scope of Research

The ergonomic that will apply when making installation of Kesidang CNC 3D Router is research and data will be collect in this topic. The purpose of study about ergonomic to identify the installation of Kesidang CNC 3D Router follow the step that has been given. The literature review, data collection and analyse data will conduct purpose to learn how ergonomic will apply in KESIDANG CNC 3D Router.

The scope of this research are as follows:

- Literature review
- Collect the data by using software Rapid Upper Limb Assesment (RULA) CATIA.
- Time taken of assembly KESIDANG by using stopwatch
- Analyze the data collected by using the level of muscular disorder (MSD) in CATIA

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Search engine used in literature review to demonstrating knowledge and understanding of the academic literature on a specific topic placed in context. A literature review also include a critical assessment of the sources. In this chapter, need to identify and examine reference materials from journals, books and sources from the internet related to the new product development process. Including in this study, there are aspects related to the NPD process, design manufacturing interphase, concurrent engineering, and the method used to collect data and analyze the collected data.

2.2 CNC 3D Router

Working with automatic mechanical equipment demands precise, accuracy, speed, consistency and flexibility. In this case it takes the help of embedded computer applications to do the job. One of the mechanical equipment combined with microcomputer that has been widely used is a CNC (Computer Numerically Controlled). CNC machines are used for mechanical work such as cutting, engraving, drilling and others. The computer technology used to control, parse and execute certain objects based on user command. In the manufacturing industry, the use of CNC machines greatly affects the increased production.

They are also capable of cutting joinery like mortises and tenons. The idea behind a CNC router and a CNC milling machine is fairly similar. One of the various tool types that have CNC variations is the router. CNC routers have three type of machine that are, 3-axis, 4-axis, and 5-axis routers. In CNC machining, material is taken out of a workpiece until the desired shape is achieved. These subtractive manufacturing machines operate on XYZ plane and have at least three axis: an X axis that runs vertically, a Y axis that runs horizontally, and a Z axis (depth). Just along the Z-axis, 3-axis mills are frequently used for drilling and tapping holes. Due to the spindle's ability to travel up and down, it is unable to enter the workpiece from the side.

Research about realization of low cost of CNC machine by (Ginting et al., 2017) discusses the development of a low cost 3-Axis CNC router. This research is main literature review on hardware dan mechanic design. Research by (Paulo, 2010) realizes a 3 axis CNC machine as well as a LabVIEW-based application program as an instruction giver. The main tools in mechanical design consist of multiplex board, stepper motor, linear bearing, ball bearing, linear shaft, leadscrew and nut, coupling beam, power supply and spindle drill. Figure 2.1 is a 3D design of CNC machine made using Autocade software and display of microcontroller-based CNC machine that has been built can be seen in Figure 2.2 (Ginting et al., 2017).

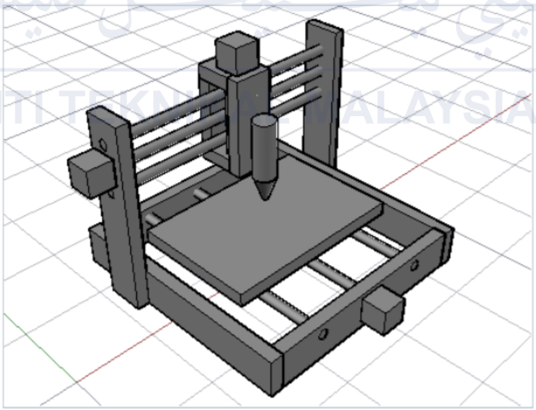


Figure 2.1CNC machine viewed from top left corner(R.Ginting, S. Hadiyoso and S.Aulia, 2017)

Figure 2.2CNC machine display (R.Ginting, S. Hadiyoso and S.Aulia, 2017)

In December 2021, a programmed called Talent Development Programmed: Developing Tomorrow's Expertise was held for Product Design Student of Faculty of Mechanical & Manufacturing Engineering Technology. As organizer of this programmed, Dr. Hambali bin Boejang has proposed a product development project which was to develop a CNC 3D Router Machine in order to share and implement the knowledge that he experienced during his time in automotive industry.

KESIDANG CNC 3D Router is a 3-axis machine that has a little difference compared to the existing CNC 3D Router 3-axis. From the physical of KESIDANG it can see that it is larger and suitable for the learning process. KESIDANG is a brand-new machine, and its creation required the work of six UTEM students, the project director, and assistance from other supervisors. The KESIDANG CNC 3D Router is the ideal computer-controlled machine for cutting and engraving a variety of materials, including wood, composites, metals, plastics, glass, and foams. A hand-held router is commonly installed on the spindle of a CNC router. Many popular carpentry shop instruments, such as the panel saw, spindle molder, and boring machine, can be replaced by CNC routers.

The KESIDANG's name was chosen as the winner of a machine naming competition. We want everyone to be aware that we are working on a machine with the potential to be used for teaching and learning. Through a machine naming competition in which 100 people took part, we selected KESIDANG as the name for the CNC 3D Router project. Both UTEM and Melaka have designated KESIDANG as their national flower. This CNC 3D Router's production goal is to at the very least get to the point of generating a working prototype. The design produced is attractive and makes this machine the choice of users in the future.

2.3 New Product Development

New product development (NPD) process is essential for the creation of products that satisfy needs of industrial customers and differentiate company among competition. The NPD process has specific character in case of industrial sector, taking into account the level of product personalization and possibilities of close cooperation with final client. NPD is a decision-making process encompassing several core functions (*Hambali,2020*). NPD can assure product quality by directing the product development activity using milestones and checkpoints/gateways. NPD refers to the process of bringing a new product to the market, starting from the planning, followed by engineering design, manufacturing engineering, and production. Figure 2.3 is the main focus of four phases in NPD (Boejang etc, 2019; Wheelwright & Clark, 1992).

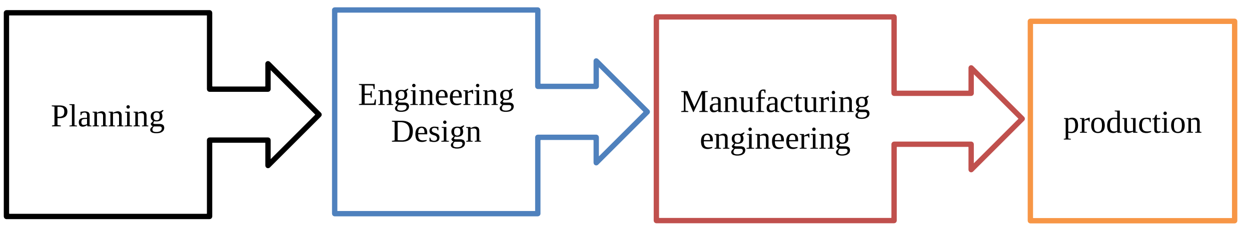


Figure 2.3four main phases(Boejang etc, 2019; Wheelwright & Clark, 1992)

1. **Planning**

Usually the initial stage of the NPD process, planning entails outlining the general approach to creating a new product. This stage prepares the ground for the remaining NPD steps and makes sure the product is in line with the aims and goals of the business. Overall, the planning phase is critical to the success of the NPD process, as it sets the direction and goals for the project, and ensures that the new product is aligned with the needs of the market and the company's objectives. Prior to the start of the product development (PD) initiatives, planning is done. It entails tasks including assessing current technical advancements, market objectives, and business strategy. (K.T. Ulrich and S.D. Eppinger, 2015).

I. Product definition:

In this phase, the project's scope, the goal of the finished product, and the target market are all identified. It entails comprehending consumer wants and creating a product that fulfils those needs.

II. Concept development:

This procedure entails coming up with concepts and ideas for the CNC 3D router. It could involve research, analysis of competitive products, and brainstorming meetings.

III. Feasibility analysis:

Examining the CNC 3D router's technical and financial viability is a step in this process. It involves examining the resources that are available, estimating the production costs, and figuring out whether the product can be produced within the intended time frame and price range.

IV. Project planning:

This procedure entails creating a thorough project plan that specifies the duties, due dates, and resources needed to create and introduce the CNC 3D router. It involves setting up a project timeline, specifying the project's parameters, and identifying any potential dangers or difficulties.

2. **Engineering design**

The engineering design phase is a critical component of the new product development (NPD) process. During this phase, the focus shifts from concept development to designing the product in detail, and preparing it for production.The engineering design phase is crucial to the success of the NPD process, as it ensures that the product is designed in a way that is both functional and cost-effective to produce. It also helps to identify and address potential issues early in the development process, which can save time and money down the road. The performance of the system is significantly impacted by design iteration throughout phases (Baxter G., Sommerville I., 2011).

I. Create a detailed product design:

Engineers will produce a thorough design for the CNC 3D router based on the product concept that was generated during the planning stage. This design will outline the machine's dimensions, components, and features as well as any technical parameters that must be met.

II. Develop a prototype:

The CNC 3D router prototype will be created after the design is finished. Before the product is released to the market, this prototype will be used to test the design and find any problems that need to be resolved.

III. Conduct testing and validation:

To make sure the prototype satisfies the necessary requirements, it will go through thorough testing and validation. Performance testing, stress testing, and quality testing are some examples of this testing.

IV. Refine the design:

The design may need to be improved upon and changed as a consequence of testing. This could entail modifying the CNC 3D router's dimensions, composition, or specs in order to enhance its functionality or address any problems that were discovered during testing.

V. Finalize the design:

A final version of the product design will be produced after the design has been improved and validated. The CNC 3D router will be produced using this design and released to the market.

3. Manufacturing engineering

Manufacturing engineering phase is where the product is ready for mass production. The design and development of the production procedures, machinery, and tools required to mass produce the new product are part of this phase. The manufacturing engineering phase, which ensures that the product can be produced effectively and efficiently at scale, is essential to the success of the NPD process. In order to save time and money and to guarantee that the final product satisfies the requisite quality standards, it is also helpful to detect and address any potential manufacturing concerns early in the development phase (Ulrich K. T., Eppinger S. D., 2015).

I. Develop a manufacturing plan:

The creation of a thorough manufacturing plan for the CNC 3D router is the initial stage of the manufacturing engineering process. This plan will detail the methods, tools, and processes that will be employed, along with any quality assurance measures that will be used.

II. Create manufacturing drawings:

Manufacturing engineers will produce precise drawings that outline the dimensions, tolerances, and materials needed to manufacture the CNC 3D router based on the product design that was produced during the engineering design process.

III. Select manufacturing processes:

The CNC 3D router will be produced using a variety of production techniques, which will be chosen in the following stage. This could entail deciding on specific gear, tools, and equipment as well as the procedure that will be followed to create the product.

IV. Create prototypes and test runs:

Manufacturers will produce prototypes and do test runs prior to beginning full-scale production to make sure that the tools and processes are functioning as planned. To find any problems that need to be fixed, this can entail small-scale testing of the production process.

4. Production

Production phase is the stage of the new product development (NPD) process where the product is manufactured and brought to market. This phase involves the actual production of the product, as well as the associated logistics, such as shipping and distribution. The product is produced using the actual manufacturing method during the ramp-up phase of production. This occasionally calls for a pilot project in which the product is made on a real production line as if it were a training exercise for production line workers. It is also a phase where any unresolved production-related issues are fixed. (K.T. Ulrich and S.D. Eppinger, 2015).

I. Assembly of components:

   The CNC 3D router's parts, including the frame, motors, and control panel, are put together in accordance with the production plans and instructions. This entails adhering to the production methods and quality assurance guidelines set during the manufacturing engineering phase.

II. Quality control:

   Throughout the whole production cycle, quality control processes are used to make sure the finished product satisfies the required criteria for quality. At various phases of the production process, testing and inspections of the product may be required. Additionally, final inspections may be necessary before the product is distributed to clients.

III. Calibration and testing:

   After being put together, the CNC 3D router needs to be calibrated and tested to make sure it is operating as it should. This entails putting the apparatus through a variety of test scenarios and making any necessary modifications to make sure it is delivering precise and reliable findings.

An effective NPD process has become an important factor for competitive advantage to to cnc 3d machine manufacturing. The NPD consists of a set of activities within integrated development phases: product planning, concept development, manufacturing, production, sales and distribution, in which a particular product is built based on the customers demand and requirements

A well-defined NPD is beneficial for several reasons, better product quality, improved information and communication through task coordination and development team assignment, better timing for project scheduling, performance benchmarking and reference for future projects (K.T. Ulrich and S.D. Eppinger, 2015). The goal of the NPD process is to create a new CNC 3D router product that meets customer needs and preferences, is manufacturable, and is profitable for the company. The process may involve extensive research and development, testing, and prototyping to ensure that the product meets the required performance, quality, and functionality standards.

The NPD process for a CNC 3D router may involve the use of specialized software and tools, such as computer-aided design (CAD) and computer-aided manufacturing (CAM) software, to design and manufacture the router. In research, Lee and Chang created a CAD/CAE/CAM system. They added that this approach might be used in courses as an additional training tool. (H. S. Lee, S. L. Chang, 2003). The process may also involve collaboration between various departments within the company, including engineering, manufacturing, and marketing, to ensure that the product is developed and launched successfully. In investigation, Tseng and Kolluri created a microcontroller-controlled three-axis CNC router. (Aktan et al., 2016)

2.4 Concurrent Engineering

Concurrent engineering (CE) is an engineering management concept and a set of guiding principles that expedite the successful completion of a product development process. (Dongre et al., 2017). In general, CE values are based on a single, but essential, premise that promotes the integration of downstream development problems with upstream production concerns. This would result in quicker development timeframes, better product quality, and lower production-development costs. The goal of concurrent engineering is to ensure that all development participants have timely access to crucial design information. For the majority of complex engineering activities, not all of the important information needed by a particular development team will be available at the outset of the task.

The capacity to share and discuss important information quickly with the appropriate experts is therefore essential for CE. Concurrent engineering (CE) is an idea that has been around for a long and is now universally acknowledged as a key enabler of quick and effective product development. This study investigates the degree to which CE best practises, as identified by a thorough literature assessment, are successfully used in businesses. A CE compliance check list was used to investigate businesses in both Belgium and Italy. The article compares and comments on the consumption trends in each nations. Additionally, specific data for each sector is provided. Finally, the positive impact of formal CE programs is proven by the data (Portioli-Staudacher, A., et, al., 2003).

The idea of concurrent engineering (CE) is the integration of product design, manufacturing, and support processes. CE is a management concept and a set of guiding principles that expedites the effective completion of a product development process. One simple but essential principle underpins the entire CE philosophy and encourages the integration of downstream problems into the upstream stages of a development process. According to (Hambali et al., 2009), if all design processes are carried out concurrently and decision-making across many groups is integrated, applying the CE can lower costs, accelerate the product development process, and increase product quality (CTQ). CE does not, however, entail carrying out each step of the product development process simultaneously.

Educating everyone should be a part of the first palace's methodical and concurrent concentration on the creation of a product or process (David Juarez, Jesus Segui, Ana Mengual, Santiago Ferrandiz, 2015). Due to the growing significance of time-to-market, concurrent engineering (CE), the practise of carrying out dependent product development stages simultaneously, has emerged during the past two decades as the standard method of new product development (NPD) (Yanjun Qian, Jun Lin, 2014).

Concurrent engineering is a term that is mostly utilised in the defence sector. Simultaneous engineering is the term most frequently used in the private sector. Integration Engineering is sometimes preferred as a means of obtaining integrated engineering. Concurrent engineering is a natural outcome of increasing global commercial competition, new computerised tools becoming available, changing social conditions, and increased needs for job satisfaction and professional growth (M.E.Merchant).

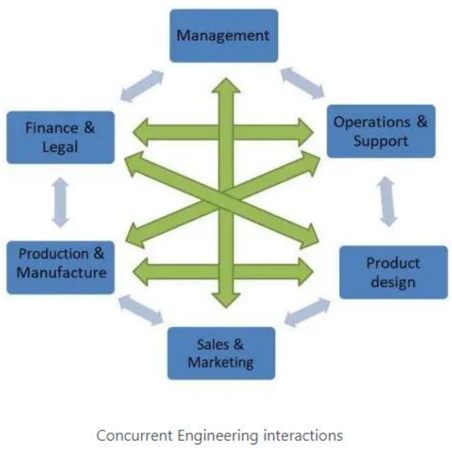


Figure 2.4Concurrent Engineering Interactions (M.E.Merchant).

2.4.1 Element of Concurrent Engineering

Concurrent engineering offers a setting that promotes and enhances communication between many departments and disciplines with the common objective of meeting the needs of engineering products. The CE concept may generally be broken down into three major components that can help reduce time, costs, increase product quality, and meet customer needs., as shown in Figure 2.(Hambali et al., 2009).

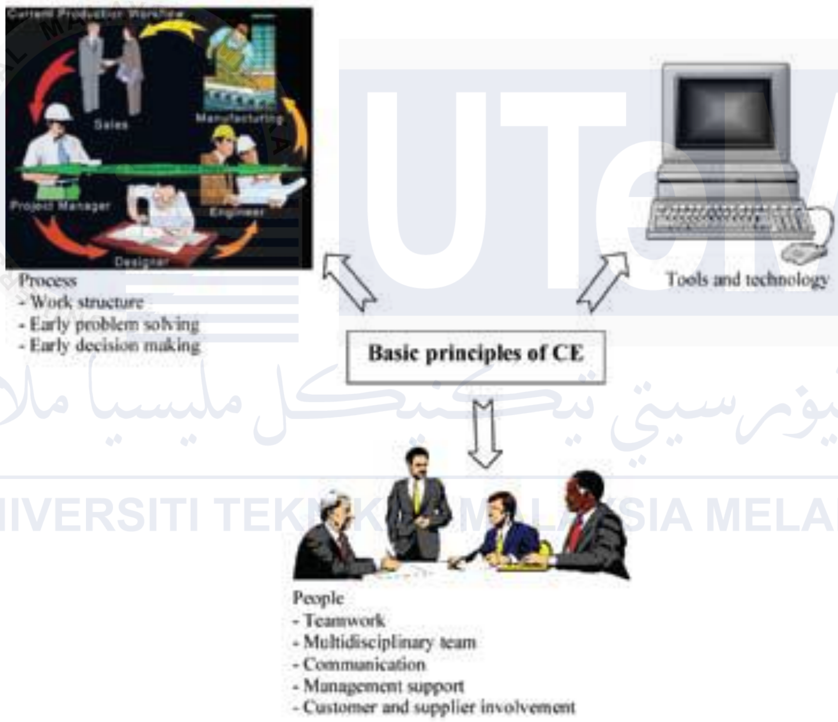


Figure 2.5Basic principles of CE (Hambali et al., 2009).

1. People

   In order to speed up product development, organisations must use the correct competent employees at the appropriate moment. Concurrent product development is a multidisciplinary team activity. Finding personnel with the appropriate qualifications, experience, and the following crucial elements is also essential.

- Multidisciplinary team to fit the product at the outset of the NPD
- Teamwork culture at the centre of the programme
- Effective teamwork and communication - sharing current and relevant information with all staff members and departments
- The shared objective of the entire organisation, from top management to lower levels of the organisational structure

2. Process

A process is a collection of product development processes that must take place in order to accomplish a task. As individuals are ineffective without processes to support their activities and decisions, these can include project planning stages, milestone management, problem-solving approaches, product development key stages, information exchange workflow, etc. The procedures listed below can be used in concurrent engineering:

- critical new product development components such as critical design stages, milestones for cross-departmental interaction, etc., are included in project planning processes and workflow management.
- Information exchange, managing engineering change, preventing specification creep, etc. are all part of the product data management workflow.
- Monitoring and checking product requirements using methods like Quality Function Deployment (QFD) across departments
- Create workflow methods for evaluation.

3. Technology

The successful use of tools, techniques, and technologies to facilitate a seamless integration of people and processes is essential for concurrent engineering to be successful. These are but a handful auxiliary tools that can be applied in a concurrent engineering setting.

- Project management software
- Product data management & product lifecycle management suites
- Quality Function Deployment (QFD)
- 3D CAD and rapid prototyping technologies, such as additive manufacturing
- Suitable FEA tools
- Evaluation tools such as DFM, DFA, DFMA and DOE
- Failure mode analysis tools such as FMEA

2.4.2 Technologies

Today's industry is finding more and more uses for computer-aided design, manufacturing, and engineering (CAD/CAM/CAE) technologies. The productivity of engineers and researchers is greatly increased by these technologies, which also enable their research activities to perform at greater levels.

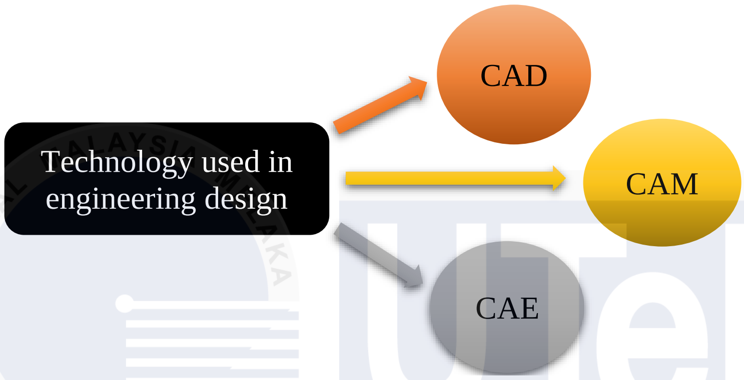


Figure 2.6Design Software

a) Computer Aided Design (CAD):

From the standpoint of (Najy, 2013), an electronic system called computer-aided design (CAD) allows for the creation of new components or products from pre-existing ones. It gives designers the ability to work with exact geometrical shapes, produce unique designs, observe their work from every angle, and use calculators to simulate how various elements would react to various stress and strength tests. Users or beneficiaries may use design data stored in memory to quickly retrieve printed copies of the drawings and specifications relevant to any part or product.

b) Computer Aided Manufacturing (CAM):

From the standpoint of (Najy, 2013) Manufacturing that utilises calculators to control cutting speeds and tool motions is known as calculator-aided manufacturing (CAM). CAM is frequently preferred over traditional production methods., especially when:

- produced by a number of various components in response to changing or periodic requirements.
- entail a challenging manufacturing procedure.
- On one section, doubling mechanism processes are occurring.
- Expert operator control and expertise are necessary

c) Computer Aided Engineering (CAE):

Design analysis and synthesis methods utilising computers and information technology (ITs) are referred to as CAE. It is anticipated that CAE technologies would enable designers to address increasingly difficult, open-ended, or integrated real-life design problems (Kim and Rezaei, 2008). For the automation of intelligent behaviours, CAE is a type of artificial intelligence. Creative thinking, on the other hand, is a skill reserved for human designers and is not covered by design automation. Automating regular tasks allows for the liberation of human designers through design (Johansson, 2011). Siemens (2016) have summarized the main advantages of CAE as follows.

- To save money and time, design candidates can be assessed and improved using computer simulation rather than actual prototyping.
- Early in the development phase, when design changes are less expensive to implement, CAE can offer performance insights.

- CAE assists engineering teams in risk management and comprehension of design performance consequences.
- Integrated CAE data and process management makes it possible for a larger community to more effectively use performance insights and enhance designs.
- The risk of a warranty being void is decreased by spotting and fixing possible issues. The expenses associated with the product life cycle can be significantly reduced when CAE is effectively incorporated into the product and manufacturing development process.

2.4.3 3D CAD Data

Engineers, product developers, and designers employ 3D CAD (3-dimensional computer-aided design) technology to produce practical, virtual prototypes of three-dimensional products. Designers can dynamically construct and alter each component, part, or assembly of a product using 3D CAD. Other areas of product engineering, including simulation testing, design and drafting, manufacturing, data management, computer-generated animation, and more, are facilitated and automated by 3D CAD software. These three-dimensional models can be rendered to produce photorealistic images for use in sales and marketing materials, sent to manufacturing as detailed drawings for production, or used in simulation studies to predict how the object will react to stress and environmental factors. 3D CAD data of KESIDANG CNC 3d router has been provide in Figure 2.9, Figure 2.10, Figure 2.11, and Figure 2.12 (Lim Kean Wei, 2023)

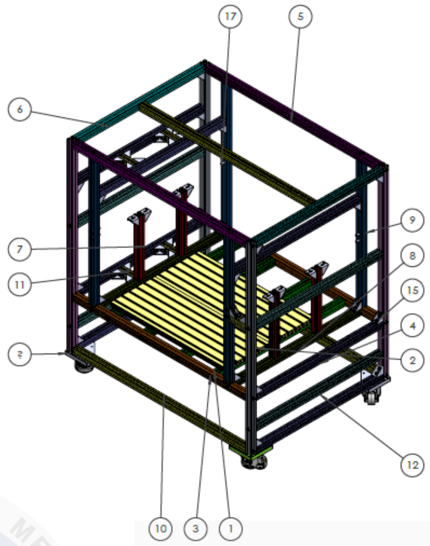


Figure 2.7Frame (Lim Kean Wei, 2023)

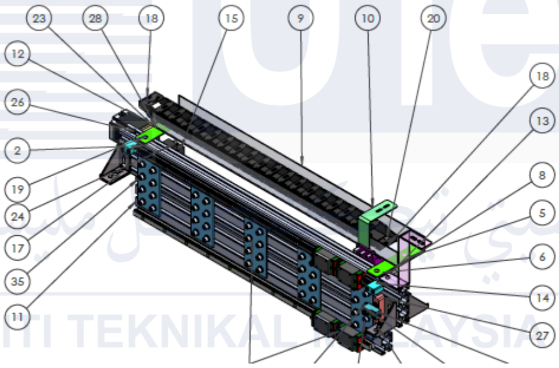


Figure 2.8X-axis (Lim Kean Wei, 2023)

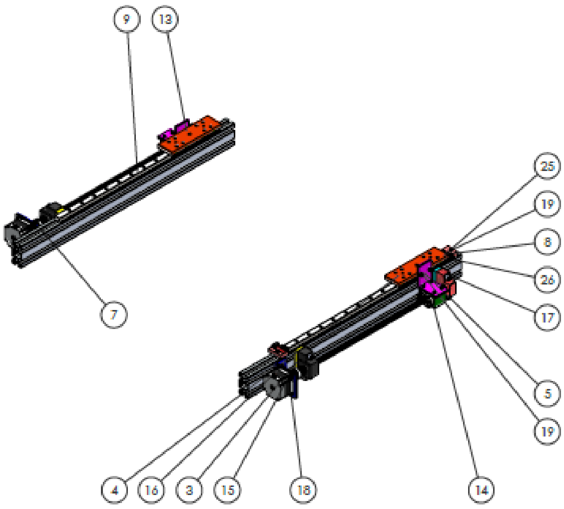


Figure 2.9Y-axis (Lim Kean Wei, 2023)

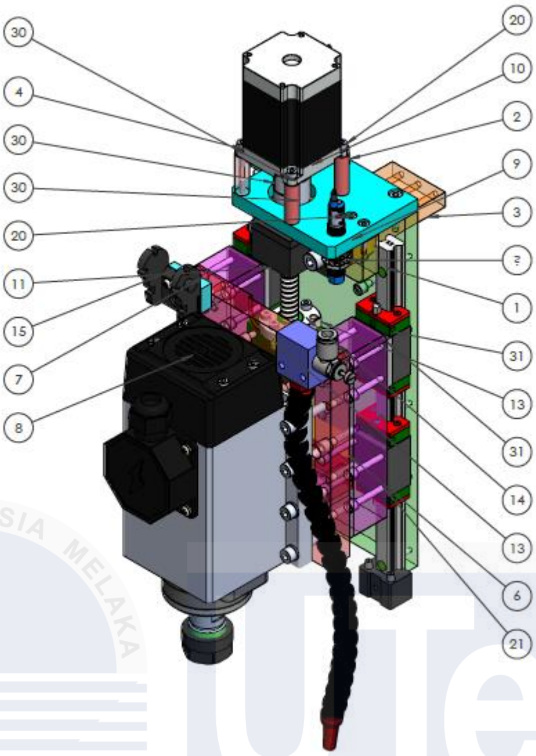


Figure 2.10 Z-axis (Lim Kean Wei, 2023)

2.4.4 Engineering Bill of Material (BOM)

A crucial component of any product is the Bill of Materials (BOM). It has been utilised as a centre of product data for product design, production planning, procurement, maintenance, and repair. It can integrate product data throughout the product life cycle (Peng Yong, Gong Jian-xing, Huang, 2011). The product makers can select different MRO service providers for the maintenance, repair, and overhaul (MRO) of the manufacturing equipment, and the various parts of the equipment may be shipped to the various MRO service providers for maintenance. The MRO system can track and document all maintenance operations for all parts during the equipment maintenance process, which enables manufacturers to plan production better and perform equipment maintenance and repairs. Additionally, numerous maintenance data files have to be included to BOM to track the upkeep actions over the course of the product lifecycle. (Huang & Shi, 2022)

Table 2.1 Table of BOM for Frame (Lim Kean Wei, 2023)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	V2_002_1000_01_MAIN BAR_00_PROFILE 30X30	690 MM LONG	4
2	V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	1000 MM LONG	2
3	V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30	940 MM LONG	2
4	V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	690 MM LONG	7
5	V2_002_1000_05_TOP LENGTH BAR_00_PROFILE 30X30	940 MM LONG	2
6	V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30	690 MM LONG	2
7	V2_002_1000_07_BASE Z-AXIS_00_PROFILE 30X30	300 MM LONG	4
8	V2_002_1000_08_BASE Z-AXIS MOUNT_00_PROFILE 30X30	690 MM LONG	2
9	V2_002_1000_09_Z-AXIS MOUNT_00_PROFILE 30X30	690 MM LOMG	4
10	V2_002_1000_10_CENTER LAMP BAR_00_PROFILE 30X30	940 MM LONG	3
11	V2_002_1000_11_CENTER SUPPORT_00_PROFILE 30X30	88 MM LONG	5
12	V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30	690 MM LONG	4
13	V2_002_1000_13_WORK BENCH_00_PROFILE	625 MM x 240 MM	2
14	MirrorV2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	1000 MM LONG	2
15	angle bracket 30x30	STD PART	48
16	Vis CHC M6x12	CAP SCREW	96
17	Vis CHC M8x35	CAP SCREW	50
18	Vis CHC M3x10	CAP SCREW	24
19	Rondelle plate serie M finition U ø 6	FLAT WASHER 6M	96
20	GDR-60-F.stp	WHEEL CASTER	4
21	V2_002_1000_14_LEVELING MOUNT PLATE_01_ALU	CASTER MOUNTING	1
22	SHBS-M6x12-SS	BTTN SCREW	16
23	MirrorV2_002_1000_14_LEVELING MOUNT PLATE_01_ALU	CASTER MOUNTING	2
24	MirrorMirrorV2_002_1000_14_LEVELING MOUNT PLATE_01_ALU	CASTER MOUNTING	1
25	Rondelle plate serie M finition U ø 8	FLAT WASHER	8
26	SHBS-M8x12-SS	BTTN SCREW	8

Table 2.2 Table of BOM for X-axis (Lim Kean Wei, 2023)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	V2_002_1300_01_X-AXIS MAIN BAR_01_PROFILE 3090	ALU PROFILE 3090* 774MM	1
2	V2_002_1300_02_MOTOR MOUNT_01_ALU	ALU BRACKET 70*35*5MM(65MMLONG)	1
3	V2_002_1300_03_FIXED START MOUNT_01_ALU	ALU 65*24*16.40MM	1
4	V2_002_1300_04_FIXED END MOUNT_01_ALU	ALU 65*20*16.40MM	1
5	V2_002_1300_05_CABLE CHAIN PLATE_00_MS	MS FLAT BAR 119*30*130MM	1
6	V2_002_1300_06_ANGLE BLOCK MOUNT_00_ALU	ALU BRACKET 60*60*5MM	1
7	V2_002_1300_07_LIMIT SWITCH BASE_01_NYLON	NYLON BLUE 60*20*15MM	1
8	V2_002_1300_08_WIRE DUCT SUPPORT_00_MS	MS FLAT BAR 130*2*30MM	2
9	V2_002_1300_09_WIRE STRUCKING_00_PLSTC	680MM	1
10	V2_002_1300_10_CABLE CHAIN PLATE_00_MS	MS FLAT BAR 80*30*80MM	1
11	V2_002_1300_11_X-AXIS LOWER BAR_00_PROFILE 3090	ALU PROFILE 3090* 764MM	1
12	57BYGH001	NEMA23 STEPPER MOTOR	1
13	BLOCK	BALL SCREW NUT BLOCK	1
14	EF10	LOWER BALL SCREW END MOUNT	1
15	thk ek10	UPPER BALL SCREW END MOUNT	1
16	SFU1204-300 With Nut	BALL SCREW SET (650MM)	1
17	Corner bracket 3060.step	ALU BRACKET 3060	3
18	Assem1	CABLE CHAIN	1
19	SHBS-M5x10-SS	BTTN SCREW	4
20	SHBS-M5x8-SS	BTTN SCREW	3
21	Vis CHC M6x12	CAP SCREW	5
22	Vis CHC M5x16	CAP SCREW	5
23	Vis CHC M4x16	CAP SCREW	36
24	Vis CHC M8x35	CAP SCREW	4
25	Vis CHC M5x12	CAP SCREW	2
26	Vis CHC M6x16	CAP SCREW	55
27	Vis CHC M5x20	CAP SCREW	5
28	M4 Nut	HEXAGONAL NUT	4
29	M5 Nut	HEXAGONAL NUT	4
30	483-040	SPRING WASHER - M4	22
31	483-060	SPRING WASHER - M6	53
32	Rondelle plate serie M finition U ø 6	FLAT WASHER	53
33	Flex Shaft	SHAFT COUPLER (8-8-30MM)	1
34	HIWIN 650M LINEAR	HGH15CA LINEAR BEARING SET	2
35	PROFILE LINK PLATE 6060-8	LINK PLATE 6060-8	5
36	PROFILE LINK PLATE 6060-4	LINK PLATE 6060-4	3
37	V2_002_1300_12_LINEAR STOPPER_00	NYLON BLUE 25*25*15	2
38	SN04-N.stp	SN04-N	1
39	Vis CHC M4x25	CAP SCREW	4

Table 2.3 Table of BOM for Y-axis (Lim Kean Wei, 2023)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	V2_002_1200_01_MOTOR MOUNT_01_ALU	ALU BRACKET 70*35*5MM (65MM LONG)	2
2	V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE)	NYLON BLUE 65*20*11.40MM	2
3	V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE)	NYLON BLUE 65*24*11.40MM	2
4	V2_002_1200_04_TOP BLOCK MOUNT_00_ALU	ALU PLATE 160*45*9MM	2
5	V2_002_1200_05_SIDE ANGLE MOUNT_00_ALU	ALU BRACKET 60*60*5MM (40MM LONG)	2
6	V2_002_1200_06_LIMIT SWITCHMOUNT_00_NYLON(BLUE)	NYLON BLUE 40*25*9MM	1
7	V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60	ALU PROFILE 3060 (690MM LONG)	2
8	MakerBot LimitSwitchBoard	LIMIT SWITCH MODULE	2
9	MGN15 with rail	LINEAR GUIDE SET	2
10	57BYGH001	NEMA23 STEPPER MOTOR	2
11	SFU1204-300 With Nut	BALL SCREW SET	2
12	thk ek10	UPPER BALL SCREW END MOUNT	2
13	EF10	LOWER BALL SCREW END MOUNT	2
14	BLOCK	BALL SCREW NUT BLOCK	2
15	Flexi_spojka_D25 L30	FLEXIBLE COUPLING	2
16	Vis CHC M5x12	CAP SCREW	10
17	Vis CHC M8x35	CAP SCREW	8
18	Vis CHC M4x16	CAP SCREW	16
19	Vis CHC M5x20	CAP SCREW	5
20	M4 Nut	HEXAGONAL NUT	8
21	SHBS-M4x16-SS		12
22	Vis CHC M3x12	CAP SCREW	24
23	Vis CHC M5x16	CAP SCREW	1
24	Vis CHC M3x8	CAP SCREW	16
25	SHBS-M3x8-SS	CAP SCREW	4
26	V2_002_1200_06_LIMIT SWITCHMOUNT_01_NYLON(BLUE)	NYLON BLUE 40*25*9MM	1
27	SHBS-M5x10-SS	BTTN SCREW	2

Table 2.4 Table of BOM for Y-axis (Lim Kean Wei, 2023)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	V2_002_1400_01_MAIN PLATE_01_ALU	ALU PLATE 275*135*15MM	1
2	V2_002_1400_02_TOP PLATE_01_ALU	ALU PLATE 135*90*15MM	1
3	V2_002_1400_03_LINK PLATE_01_ALU	ALU PLATE 55*60*20MM	1
4	V2_002_1400_04_BUSH PIPE_00_ALU	ALU HLLW PIPE D10*I.DM4*40MM	4
5	V2_002_1400_05_SPACER PLATE_00_ALU	ALU PLATE 75*30*25MM	2
6	V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU	ALU PLATE 150*175*17MM	1
7	V2_002_1400_07_CABLE CHAIN SPACER_00_ALU	ALU PLATE 40*25*15MM	1
8	V2_002_1400_09_BLOCK SPACER_02_ALU	ALU PLATE 155*40*40MM	2
9	V2_002_1400_12_LIMIT SWITCH BASE_00_NYLON	NYLON BLUE 40*35*17MM	1
10	57BYGH001	NEMA 23 STEPPER MOTOR	1
11	thk ek10	UPPER BALL SCREW END MOUNT	1
12	EF10	LOWER BALL SCREW END MOUNT	1
13	SFU1204-300 With Nut	BALL SCREW SET 240MM	1
14	BLOCK	BALL SCREW NUT BLOCK	1
15	1825	CABLE CHAIN	2
16	Vis CHC M4x10	CAP SCREW	16
17	Vis CHC M5x16	CAP SCREW	3
18	Vis CHC M4x20	CAP SCREW	10
19	Vis CHC M8x50	CAP SCREW	4
20	Vis CHC M4x16	CAP SCREW	20
21	Vis CHC M4x30	CAP SCREW	16
22	Vis CHC M5x25	CAP SCREW	6
23	Vis CHC M5x12	CAP SCREW	2
24	Vis CHC M6x30		8
25	SHBS-M4x10-SS	BTTN SCREW	4
26	MSTH5-25.step	PART--DESC	4
27	483-040	SPRING WASHER - M4	42
28	483-050	SPRING WASHER - M5	9
29	483-060	SPRING WASHER - M6	8
30	Flex Shaft	SHAFT COUPLER (8-8-30MM)	1
31	HIWIN 250MM LINEAR	HIWIN HGH15CAZ0 280MM	2
32	COOLANT		1
33	GDZ80X73-1.5	SPINDLE ER20 220V 6000RPM 3.2NM	1
34	Vis CHC M5x20	CAP SCREW	3
35	HG15 STOPPER		2
36	CHINA_Sensor Inductive Proximity_LJ12A3-4-Z.stp	Inductive Proximity Sensor Switch\nLJ12A3-4-Z/AX (LM12-3004NB)\n4mm NPN NC\n6-36V	1

2.4.5 Design Preliminary Approval

The term "Design Preliminary Approval" (DPA) refers to the approval that comes after the theater's preliminary cost estimates and is meant to signify that the theatre and the director have approved the preliminary design in light of both financial and creative factors. If the Preliminary Design concept needs to be modified or changed in order to receive approval, the Designer will do so and submit the updated work in the same Preliminary Design format as before. The Theatre must approve in writing and copy the Director when doing so. No more work on the design may be done before receiving such permission. In essence, approval is a directive to the Designer to move on to the Completed Design stage.

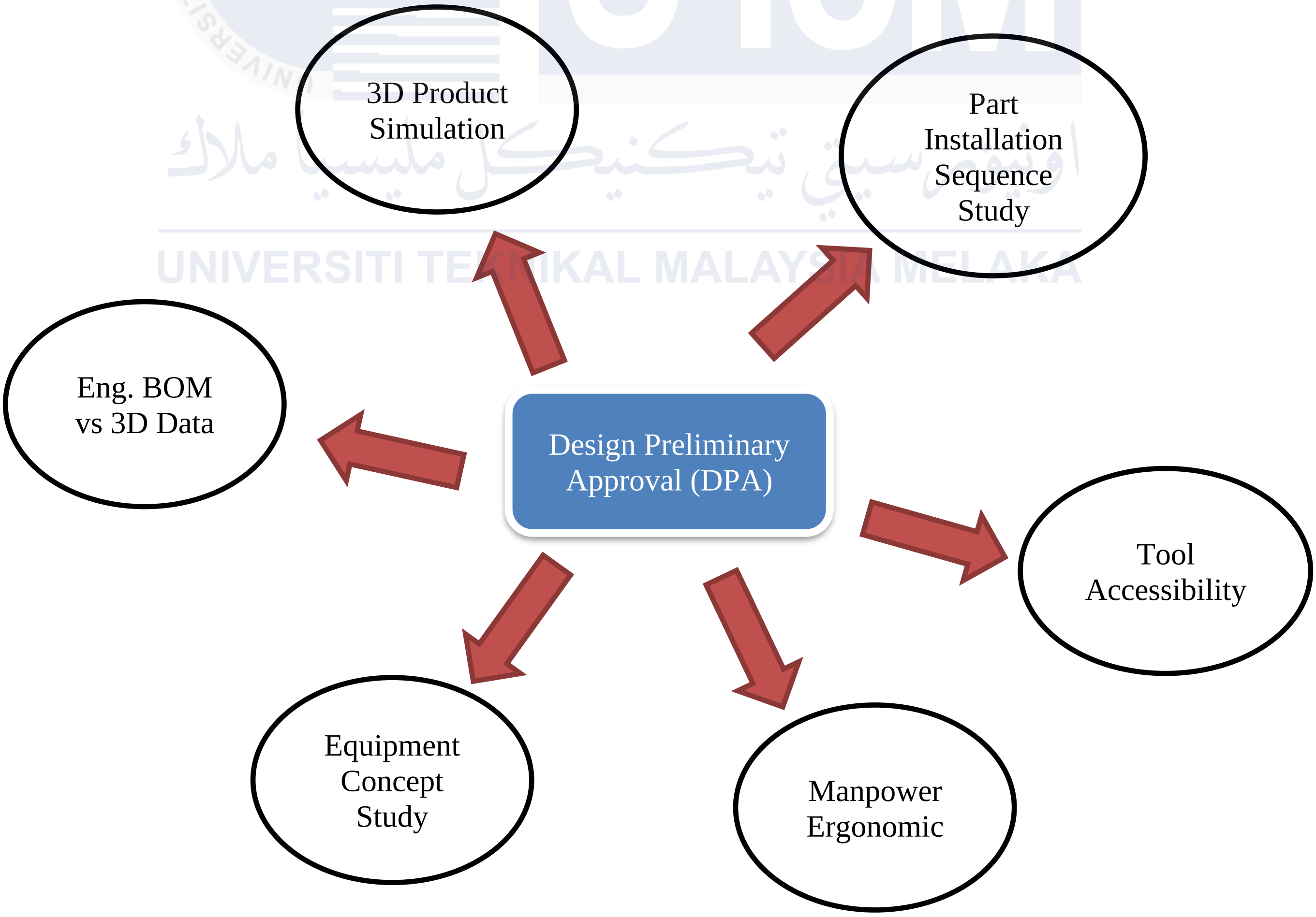


Figure 2.11 types under Design Preliminary Approval

3D Product Simulation

The term "3D simulation technology" refers to a contemporary professional technology that implements 3D simulation with the aid of a computer by using model theory and certain pertinent data. With the development of 3D simulation technology, it has become increasingly common in scientific research across all fields, has started to play a significant role in technical evaluation of the national computer field, and is increasingly intertwined with national security. By adopting 3D simulation technology, which is no longer constrained by theoretical studies and trial experiments, people can differentiate things more objectively. The 3D simulation concept should always serve as the foundation for the use of 3D simulation technology in the creation of industrial products (Huang & Shi, 2022), so that 3D simulation technologies can play a better role.

Design preliminary approval may be related to 3D product simulation. It is an important tool that can help with the assessment and verification of a product design at the initial approval stage. Designers can get important insights into the performance, functionality, and ergonomics of the product by using 3D product simulation as part of the design preliminary approval process. It assists in minimising expenses, lowering the number of design iterations, and guaranteeing that the final design satisfies all relevant criteria.

Part Installation Sequence Study

Numerous industrial uses of Design for Assembly & Design for Manufacture (DFA/DFM) have been successful. There is some evidence, though, that suggest that not all of the industrial community has taken the DFA principles' teachings to heart. One investigation (Barnes et al., 1997) found that on average, Current items undergo more complicated assembly processes and contain about 50% more pieces than is necessary. Particularly in sectors like manufacturing, construction, or projects based on assembly, part installation sequence studies may be pertinent to design preliminary approval. It entails examining the sequence and technique used to install or assemble components or parts during the manufacturing or construction process. Designers and stakeholders can evaluate the effectiveness, ergonomics, and viability of the assembly or installation process during design preliminary approval. It aids in designing in a way that makes construction or manufacturing processes simple, secure, and effective.

Tool Accessibility

Tool accessibility is an important factor to take into account when approving a design, especially when designing workspaces, pieces of equipment, or finished items that need tools. Accessibility to and use of tools during work or operation is referred to as tool accessibility. Potential problems with usability, effectiveness, and safety can be found and fixed early on by addressing tool accessibility during the design preliminary approval stage. It supports ergonomic concepts, encourages user-centered design, and improves overall usability and productivity.

Man power Ergonomic

Considerations for workforce ergonomics may be essential to develop preliminary approval procedures. To ensure the health and performance of the people using or engaging with the design, it is crucial to evaluate if the design follows ergonomic principles while examining a design concept or proposal. Potential ergonomic problems can be recognised early by including personnel ergonomic concerns in the design preliminary approval process, enabling the necessary alterations to be made before the final design is implemented. This ensures that the design fosters user convenience, security, and efficiency.

Equipment Concept Study

It is true that equipment concept studies are important for design preliminary approval, especially in projects where new machinery or equipment is being produced or suggested. It entails assessing and investigating various equipment concepts to evaluate whether they are practical, functional, and appropriate for the intended use. The feasibility, utility, and viability of the suggested equipment concepts can be evaluated by designers and stakeholders by conducting an equipment concept research as part of the design preliminary approval process. It aids in decision-making, design improvement, and ensuring that the project's criteria and objectives are met by the final equipment design.

Eng. BOM vs 3D Data

Both 3D data and the engineering bill of materials (BOM) are pertinent to the preliminary approval of a design, but they have different functions and offer different information. Eng. BOM includes a thorough breakdown of the necessary parts and supplies, whereas 3D data delivers a picture of the design. Eng. BOM and 3D data both support design preliminary approval by permitting assessment of several factors, including component availability, cost, visual appeal, and functional qualities. They offer crucial data for evaluating the design's viability, manufactureability, and general fitness for the intended use.

1. Engineering Bill of Materials (Eng. BOM):

   A complete list of all the materials, parts, and components needed for a system or product is included in the engineering BOM. It contains information like part numbers, descriptions, numbers, and specs. The engineering BOM is frequently referred to and used in the production, assembly, and procurement processes. It guarantees that all required parts are present andaccounted for and offers crucial data for cost estimation and supply chain management. (*Haik, Yousef, et al., 2018*).

2. 3D Data:

The term "3D data" refers to a digital representation of a three-dimensional design, frequently produced with CAD software. Drawings, CAD models, and other visual representations of the design are included. Stakeholders can see the product, look at its geometry, and comprehend its form, structure, and spatial relationships thanks to 3D data. It is helpful for evaluating the design's appeal, functionality, and ergonomics. (Douglas Bryden and Peter Childs, 2014).

2.4.6 Design Manufacturing Interface

The area where the design and manufacturing processes converge and interact is known as the design-manufacturing interface (DMI). The design specifications are converted into production procedures and instructions at this stage of the new product development (NPD) process, and manufacturing feedback is then incorporated back into the design process.

The manufacturing team and the design team collaborate during the DMI phase to make sure the product is developed with manufacturability in mind. This implies that the design team must take into account how the product will be produced, the materials and techniques that will be employed, as well as the method of assembly. The product must be created to meet quality and legal criteria, according to the design team. In order to choose the optimal production procedures, tools, and materials to employ when making the product, the manufacturing team must also analyse the design data. The manufacturing team must inform the design team of any design elements that might be challenging or expensive to produce.

Within a manufacturing organisation, there are many different functions. Three key roles—marketing and sales, design, and manufacturing—are involved in the successful product design and production (Chase et al.,1998) as shown in fig. 2.4. The multiple activities that these functions complete during the design and production of a product often take place in a sequential order. Marketing is in charge of determining the demands and trends of the market today and coming up with fresh product concepts

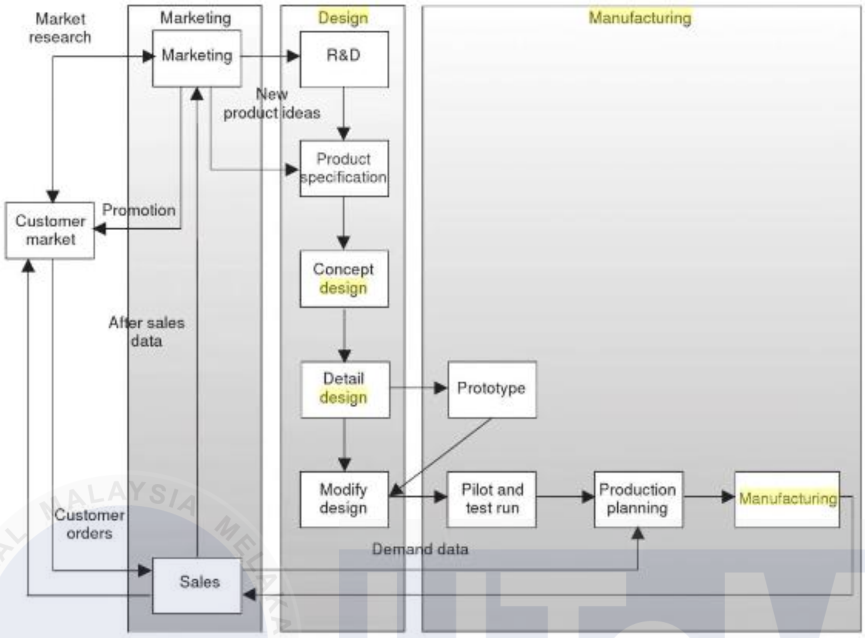


Figure 2.12 main functions involved in product design and manufacture (Chase et al., 1998

The specifications for the product and the procedure that were created during the design and development stage are then given to the production function. The detailed work instructions required to produce the product will be drafted using these. The manufacturing plant will thereafter get these for use. Consequently, even though the manufacturing and design functions are separate, the process planning activity connects them as in fig. 2.5 (McMahon and Browne, 1993). Process planning is the design/manufacture interface in this sequential approach.

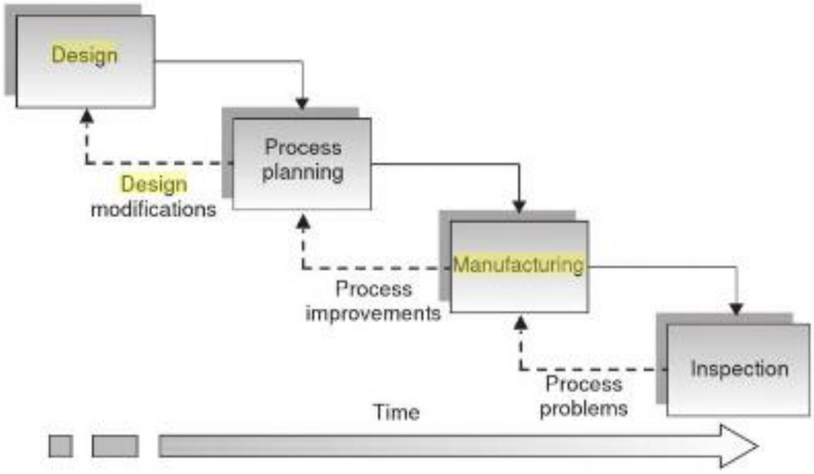


Figure 2.13 process planning - design/manufacture interphase (Addison Wesley Longman Limited)

The sequential design and production of items has relied on a long product life cycle, or consistent demand for the product over a protracted period of time. The time it takes to create and manufacture items, or the "time to market," as it is often called, has forced manufacturing companies to think of ways to shorten this process. Simultaneous or contemporaneous engineering is the name for this collaborative strategy based on the usage of cross-functional teams. The functions of such cross-functional teams include (Evans, 1996):

- Ensuring all team members understand enough about the product functions to be able to contribute to the design decisions

- Determining the appropriate design and manufacturing methods to use

- Relating all product functions to manufacturing methods

2.5 Ergonomics

The Greek words "ergos," which means "work," and "nomos," which means "laws of," are the roots of the word ergonomics. Therefore, ergonomics can be simply translated as "the laws of work." The purpose of ergonomists is to fit the demands and requirements of the job to the abilities and capabilities of the worker. The term ergonomics was first used in literature (Sluchak, n.d.), a Polish educator and scientist (Sluchak, n.d.). But it wasn't until 1950 that one of the field's pioneers, K.F.H. Murrell, "reinvented" ergonomics for application in the modern world. Today, it is challenging to locate a consensus definition of ergonomics. However, the following definition should suffice:

The study of human behavioural and biological traits is known as ergonomics, and it is used to determine how best to construct the living and working environments.

Ergonomics and human factors are interchangeable terminology. If a distinction between ergonomics and human factors is made, it is solely from a historical standpoint. The term "ergonomics," as it developed in Europe, typically concentrated on questions of how employment affected the individual, with the aim of reducing weariness brought on by the job. Contrarily, human factors in the United States emphasised how people acted in regard to their working environment and the equipment they came into contact with (Sluchak, n.d.)

However, there is a line that ergonomic experts continue to draw between study and implementation. Ergonomics is seen as the study of humans with the goal of gathering information and formulating general rules about human traits. Applying facts and principles to the design of tools and systems for people is known as applied ergonomics. Applied ergonomics and human factors engineering are interchangeable terms (Christensen, 1988).

2.5.1 Distinguishing Features

Ergonomics has two defining characteristics: it is interdisciplinary and takes a systems approach to the link between people and their jobs. These characteristics work as a unit to distinguish ergonomics from other fields.

2.5.1.1 Interdisciplinary Nature

In order to get pertinent information about a situation, ergonomics is interdisciplinary in nature and pulls from all fields of science and humanities. The frequently consulted subject areas are known as ergonomic databases.

TABLE
Ergonomic Databases

Disciplines Consulted	Knowledge Used
• Ergonomics	
○ Human performance	—Motor skills —Reaction
○ Biomechanics	—Muscular strength —Coordination
○ Anthropometry	—Body dimensions
• Psychology	—Attention —Motivation
○ Perception	—Sensory recognition
○ Cognition	—Memory —Decision making
• Life Sciences/Medicine	—Vision, audition, etc. —Human physiology —Effects of stress
• Engineering	—Time and motion analysis —Equipment design
• Personnel management	—Training techniques

Figure 2.14 table ergonomic databases

Ergonomists have access to information on anthropometry, biomechanics, and human performance within the topic of ergonomics, but they also contact experts from other disciplines. For instance, ergonomics makes extensive use of psychological research from several fields to understand how people process and acquire information that is relevant to mental tasks. Similar to this, ergonomics utilises knowledge about human physical/physiological capacities for manual tasks from the life sciences. The ergonomist is able to approach an occupational environment from a larger, systems viewpoint because of their openness to draw on information from various disciplines.

2.5.1.2 System Approach

The person is at the heart of the systems approach. The components of the tool, task, and workstation have an immediate impact on the human. Finally, the total environment is made up of physical aspects and other managerial or operational elements that may have a direct or indirect impact on people or other components. The term "workplace" or "job" in this article refers to a grouping of components including a task, tool, workstation, and surroundings.

Ergonomists focus on the human and how the components of the surrounding workplace affect the human when using the systems approach. The principal worker is typically taken into account (for example, an assembler, a secretary, or a dock worker), but other employees who occasionally work nearby and who can be impacted by the workplace are also taken into account (for example, managers, housekeepers, or installation and maintenance professionals). To evaluate the influence on the human of all the workplace components, either individually or collectively, ergonomic databases are used to gather knowledge of human capabilities and limitations.

2.6 Anthropometry

The measurement and proportions of the human body are the subject of anthropometry. Designers may make items that fit a variety of body shapes and sizes by understanding anthropometric data, which is crucial for assuring comfort and lowering the risk of damage. According to (Pradu-Lu JLD, 2007), the measurement science and art known as anthropometry determines the physical geometry, mass characteristics, and strength capacities of the human body. It entails the methodical measuring of a human body's physical characteristics, especially dimensional descriptors of body size and shape. For those creating new workplace furniture and equipment, understanding body measurements is crucial. The optimal design of the work areas depends on the anthropometric dimensions (Singh, 2013). For the purpose of rationalising the design of agricultural hand tools and equipment, anthropometric data on female agricultural workers are especially crucial (Philip GS, Tewari VK, 2000) and (Tewari VK, 2004).

When determining the dimensions of a workstation or design, three key variables—sex, age, and race or ethnicity—that affect body size variations must be taken into account. If the equipment or tools are inappropriate for the job, they will exacerbate occupational disorders despite decreasing labour load. A higher frequency of both acute and subacute cumulative injuries of the hand, wrist, and forearm is linked to poor tool design and overuse (Singh, 2013). Hand tools, equipment drawn by animals, and tractor- and power-operated machinery are all widely employed in Indian agriculture for a variety of tasks. These devices are either controlled or operated by human beings (Singh, 2013). Anthropometric information can be used to design equipment properly for increased comfort and efficiency. There are significant differences between the anthropometric data of Indian and Western people, according to available anthropometric data for Indian agricultural labourers that could be relevant in farm machinery design (Singh, 2013), (Sen RN, Nag PK, Ray GG, 2003) and (Gupta PK, Sharma AP, Gupta ML, 1983).

2.6.1 Material and Methode

The Herpenden Anthropome was used to measure the anthropometric characteristics of farm women. These measurements included vertical reach, vertical grip reach, eye height, acromial height, elbow height, olecranon height, metacarpal height, knee height, arm reach from the wall, chest breadth, vertical grip reach sitting, sitting eye height, buttock popliteal length, hip breadth sitting, elbow-elbow breadth sitting, shoulder grip length, hand breadth at metacarpal The subjects were vetted to ensure that only those in good health, free from significant illness or physical impairment, would be chosen. Care was taken when measuring body dimensions to prevent overly compressing the underlying tissues and to accurately record the measurement (Singh S, Ahlawat S, Pandya S, Prafull B, 2013).

2.6.2 Design Constrain and Criteria

A constraint in anthropometrics is an observable, ideally measurable trait of people that has an impact on how a certain item is designed. A criteria is a benchmark of judgement that can be used to assess how well a user and an artefact match. Different hierarchical levels of criteria can be distinguished. The top general criteria, also known as high-level, general, or primary criteria, include things like comfort, safety, efficiency, aesthetics, and others.

Practically speaking, the "middle-out" approach or starting in the centre of the hierarchy is frequently the best course of action. Therefore, we will focus on four sets of restrictions that, combined, account for a significant amount of the everyday issues in anthropometrics as a whole and ergonomics. **Clearance**, **reach**, **posture**, and **strength** are the four anthropometrical cardinal restrictions.

a) Clearance

It is important to leave enough head, elbow, and leg room when constructing workstations. Environments must allow enough room for mobility and access. Handles ought to have enough openings for the fingers or palm. These are all restrictions on clearance. A comparable criterion of maximum allowable dimension to exclude persons (or a portion of their bodies) is required in a few safety-critical situations. A safety guard on a machine tool would be an illustration of this, where a maximum gap size would be defined to prevent fingers from coming into contact with the machine's moving parts.

b) Reach

An apparent example of a reach constraint is the ability to grasp and use controls, as well as the constraint on seat height described above or the capacity to see above a visual impediment. The distance at which a display screen should be positioned in order to make the text on the screen comfortable to read is another illustration of a visual reach limitation. The object's maximum allowable dimension is determined by the reach constraint.

c) Posture

The link between a person's body measurements and those of the workstation will influence the person's working posture. Since posture will almost probably be impacted by more than one aspect of the workplace, postural issues are typically more complicated than clearance and reach issues.

d) Strength

The use of force in the use of controls and other physical tasks is a fourth restriction. Strength restrictions frequently provide a one-way constraint, and this is sufficient to establish the amount of force that a weak user will tolerate.

2.7 Data Collection

The quality of obtaining results can be overshadowed by the data gathering phase of a research study because it reduces the likelihood of errors that could come later in the process. In order to get the right results, a strong study design must also be combined with a lot of quality time spent on data collecting. This is because incomplete or wrong data make it impossible to guarantee the correctness of the findings (Taherdoost, 2021). On the other hand, while an appropriate data collection strategy aids in the planning of sound research, it cannot always ensure the success of the research endeavour as a whole (Olsen, 2012). The sort of data needed for the study should be identified before choosing a data collection technique (Taherdoost, 2021). This section seeks to give a brief overview of potential data kinds before exploring various data collection techniques and sources depending on these categories. Data is the actualized information in the form of numbers or facts used to analyse for various calculations and ultimately provide a conclusion to answer the research question or perform a hypothesis test (Hurrel, 2005). Different methods, including quantitative and qualitative ones, can be used to categorise data.

2.7.1 Quantitative data

Quantitative data is defined as numerical data that is produced and computed mathematically. Quantitative data can be measured using a variety of scales, including nominal, ordinal, interval, and ratio scales (Kabir, 2016). Scales can also be divided into two main categories, "Rating Scales and Attitude Scales." In order to evaluate the points or categories, rating scales give them a numerical value. On the other hand, more sophisticated techniques include attitude scales that assess people's dispositions towards any person, phenomena, or item (Taherdoost, 2016b).

2.7.1.1 Rapid Upper Limb Assessment (RULA)

Numerous tools that employees use today still do not match their anthropometry, which can lead to uncomfortable work postures like bending. These unnatural positions are easily exhausting (Yusuf et al., 2016), musculoskeletal disorders. Workers and farmers frequently experience fatigue and musculoskeletal issues.

To address these issues, a review of work posture and alternative tool changes were made in an effort to reduce subjective disorders among workers and speed up work. Utilising the RULA (Rapid Upper Limb Assessment) approach is just one of numerous work posture analyses that fit. RULA is a technique for evaluating the posture, movement, and style of a working activity that involves the use of an upper limb. The risk of abnormality that a worker will encounter while performing his or her job can be investigated using this method. The RULA approach allows us to:

a) perform a preliminary analysis to estimate how much the risk of injury elements, such as posture, static muscular contraction, repeated movement, and style, will affect a worker.

b) based on the danger of injury, prioritise the work.

c) By contrasting the evaluation of a work before and after an improvement, you can determine how much of an impact the improvement had.

This method yields a maximum limit score and a variety of work postures, with limit scores ranging from 1 to 7 (Yusuf et al., 2016).

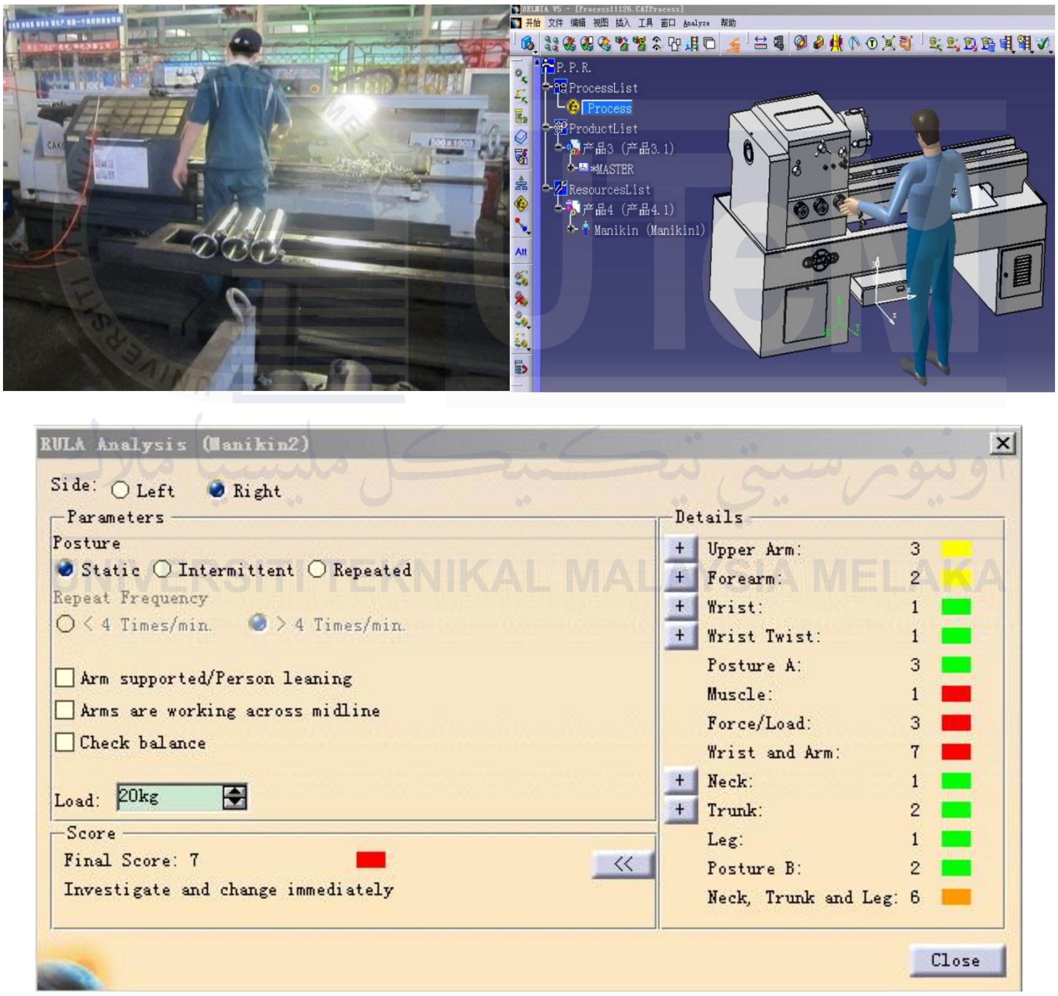


Figure 2.15 the result analysis (Liang et al., 2021)

2.8 Assembly Line

For the purpose of producing standardised goods in large quantities at low cost, the assembly line concept has been established (Saif et al., 2014). They are the flow-oriented production systems, in which various activities are carried out on work pieces using specific production equipment. In an assembly line, stations are the various locations where the equipment for working on the work pieces is set up. On an assembly line, these stations are typically placed in a specific order. Production businesses allowed for product customization, which led to the development of effective flow line systems for low volume products and a new vocabulary for mass customization has been developed (Saif et al., 2014)

2.8.1 Workflow Characteristic

Based on the characteristics of the workflow, there are two types of assembly lines. These include paced assembly lines and un-paced assembly lines.

In paced assembly lines, each station moves the finished products to the next station at the conclusion of its cycle time (CT), which is believed to be the same for all stations. The duties assigned to some stations in these assembly lines may be completed before time CT, but these parts must still wait and cannot go to the next station until time CT has elapsed. In these assembly lines, the finished parts are often moved from one station to the next using a conveyer belt.

In un-paced assembly lines work pieces are when they have completed a station, they are transferred to the following station. Based on the movement of the completed parts from the stations, there are two main kinds of un-paced assembly lines. Un-paced synchronous assembly lines transfer completed parts from all stations at once. There are no buffers between the stations in these systems because all stations move their completed pieces at the same time after a set period of time. If the task time is assumed to be deterministic, they resemble paced lines. Some study has been done in these assembly lines to take the balancing issue and the throughput estimation into consideration (Urban T L, Chiang W C., 2006). Each station in an un-paced asynchronous assembly line may have a varied cycle time that is proportional to its workload. In these systems, it's possible that the subsequent station's work may not have been completed when parts are finished on one station. In this case, the station that has already completed its job might have to wait until the subsequent station is ready. Similar to this, if a station completes its tasks, there is a chance that the station positioned before it may not have completed all of its tasks. In this instance, the station stays idle until the preceding station can transmit it its finished piece

2.9 Time Study

Every business, but notably small and medium firms, has to measure working hours. At this level, businesses frequently neglect the conventional working hours in their operations. Working time regulations prevent manufacturing processes from becoming ineffective, which results in labour and time waste. Working time is measured by keeping an eye on the company's operations and production processes, as well as how long it takes to create a product or provide services and how long it takes to complete specific tasks under typical circumstances (work standards) (Budiman et al., 2019).

Ghozali & Hermansyah (2016) said that one of the crucial factors that the production system needed to pay greater attention to was working time. Working time contributes to work productivity and serves as a benchmark for choosing the most effective way to complete a task. The endeavour to determine the average time required to accomplish a task is connected to work time measurement. (Febriana, Lestari, & Anggraini, 2015). According to Tarigan (2015), standard time is the amount of time required by a worker with the necessary expertise to do a task at a typical level of pace and conditions, including any rest time, personal needs, and other demands.
Based on these, one approach that needs to be created and used in businesses is working time measurement since it may create a balance between the human contribution and the output units produced. The application of this working time measurement technique attempts to solve the issues that come up during production activities and aid in the improvement of those activities' effectiveness and efficiency.

2.9.1 Normal Time

The amount of time needed to complete the task for the operator who worked at the gate, as determined by searching the first real time. As a result, normal time must be computed using the ranking elements for performance; in line with ILO regulations, it is helpful to ascertain the cycle time and the worker threshold (Business & Research, 2017). The Westinghouse approach will be used for performance rating, taking four factors into account. A portion of the latter factor is determined by skill and effort behaviour, followed by consistency and conditions (Business & Research, 2017).

Normal Time = (average element time) x (Performance Rating / 100)
= (19.24 second) x (1.19 / 100)
= 22.90 second

The normal time for this operation is 22.90 second

Skill			Effort		
+0.15	A1	Superskill	+0.13	A1	Excessive
+0 13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0 08	B2		+0 08	B2	
+0 06	C1	Good	+0 05	C1	Good
+0 03	C2		+0 02	C2	
0.00	D	Average	0 00	D	Average
−0 05	E1	Fair	−0 04	E1	Fair
−0.10	E2		−0 08	E2	
−0 16	F1	Poor	−0.12	F1	Poor
−0 22	F2		−0 17	F2	
Conditions			**Consistency**		
+0 06	A	Ideal	+0 04	A	Perfect
+0 04	B	Excellent	+0 03	B	Excellent
+0.02	C	Good	+0 01	C	Good
0 00	D	Average	0 00	D	Average
−0 03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

Figure 2.16 Performance Rating Table (Westinghouse)

2.9.2 Standard Time

Based on the amount of unknown vehicles coming and leaving on that day, as well as the specified goal standard time turn in and turn out for each vehicle that will be in operation. Direct measurement with the use of a research to determine the suggested stopwatch time for the parking service implementation (Business & Research, 2017).

$$\textbf{Standard time} = \text{Normal time} \times (1 + \text{allowance factor})$$
$$= 0.0664 \text{ min} \times (1 + 0.2)$$
$$= 0.0797 \text{ min}$$

CHAPTER 3

METHODOLOGY

3.1 Introduction

Chapter 3 highlights the research methodologies that will be used to achieve the RULA method (Rapid Upper Limb Assessment). The upper limbs (shoulders, elbows, and wrists) as well as the neck and trunk are primarily evaluated using the RULA approach. It pertains to activities where the operator primarily employs his upper extremities, whether or not they are moving. Examining how the NPD process, concurrent engineering, and design manufacturing interface affect project objectives is the practical goal of this study. This study's objective also to investigate the impact of manpower ergonomics on project objectives. The quantitative approach use is RULA software. The research technique is described in more detail, including the ways that data are gathered, including case studies and the observation of people's posture.

3.2 The Overall Process Flowchart

A flowchart is a graphic depiction or diagram that uses different symbols, shapes, and arrows to illustrate a process or system. It offers a visual representation of a process's decision points, flow of information, and order of steps. A flowchart's goal is to reduce the complexity of systems or processes into understandable visual depictions. A process is represented by a symbol. A separate graphic represents each step in the process and gives a brief description of that step. The top of the flowchart will mark the beginning.

Before starting data collection, the project title is chosen, and the research topic is studied. Once the survey has been circulated, the data analysis is finished. Figure 3.1 shows the complete course of the research flowchart. The whole flow study that the researcher conducted on PSM1 and PSM2 is shown in the process flowchart.

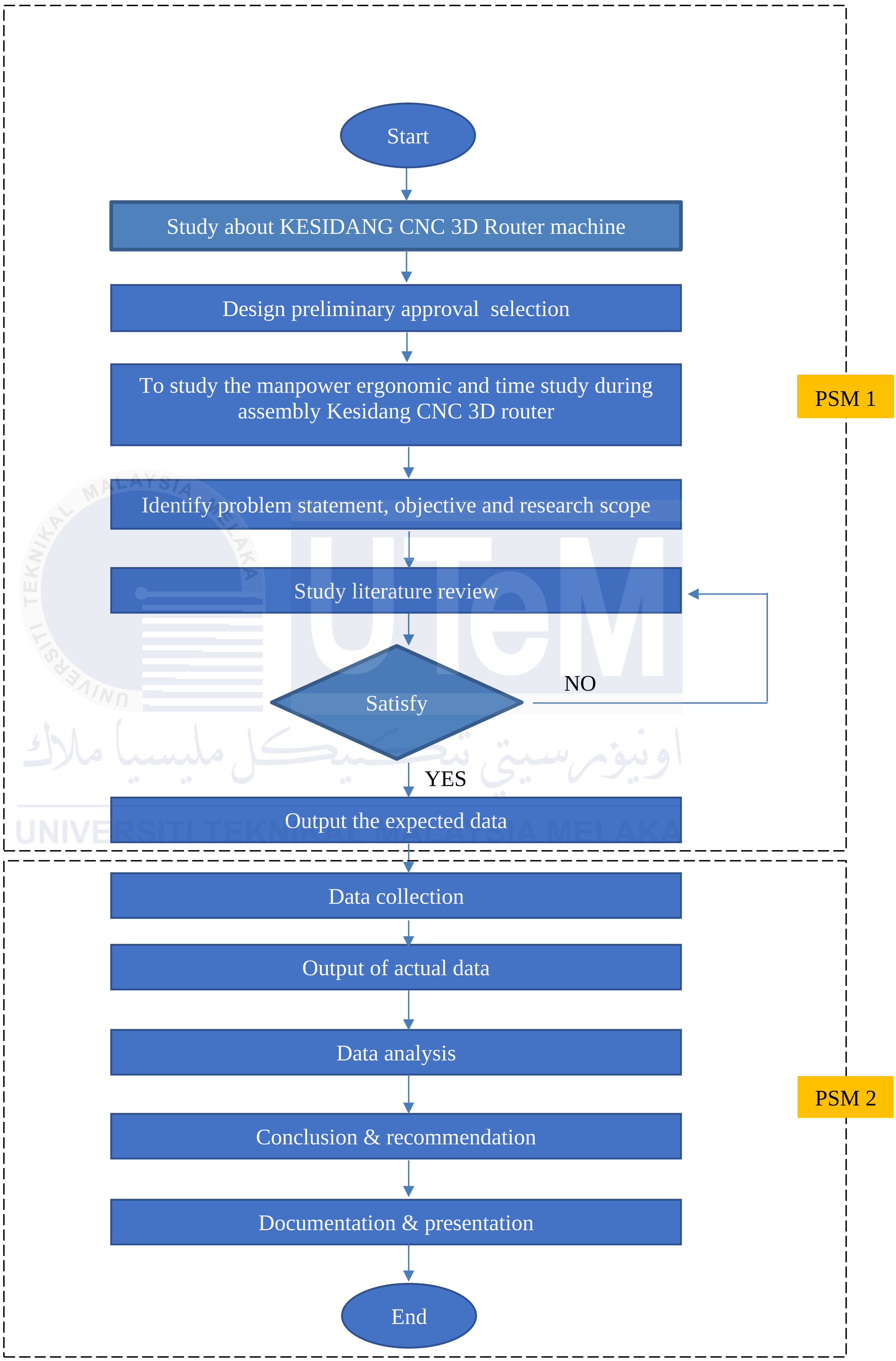


Figure 3.1Overall Process Flowchart

3.3 Research Methodology

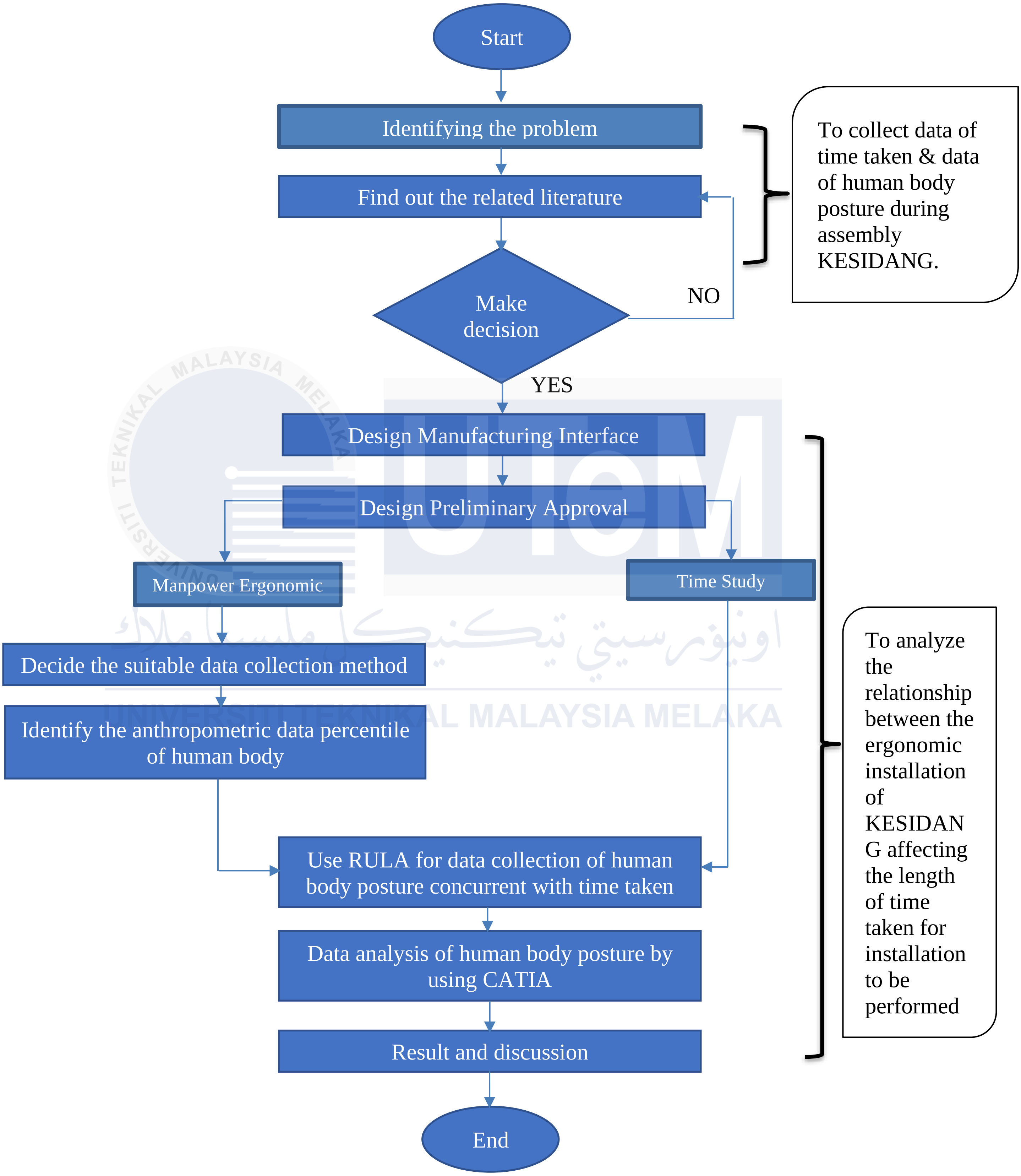


Figure 3.2 Research Methodology

3.4 Research Design

This section has provided an explanation of the procedure and methodology employed in data collection operations. In this study, there are two categories used to collecting data, secondary data and primary data. After doing a literature search in prestigious journals, books, and websites, secondary data was acquired. RULA were used for data collecting method of primary data. In primary data, the anthropometry of human body also used to help collecting the data. In addition, manikin human builder will be used as a guideline to use in the CATIA software to get expected result and actual human body posture when installing the KESIDANG to get the actual result.

3.4.1 Research Stage and Data Collection

According to the research objectives, the study was divided into two main phases as shown in Figure 3.3.

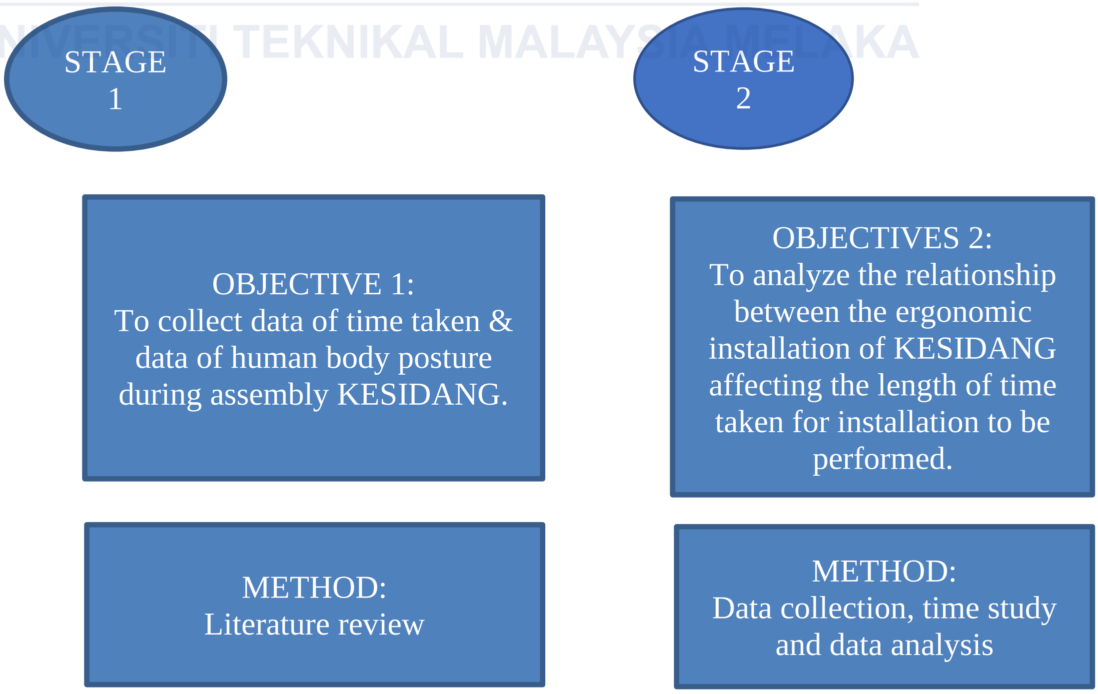


Figure 3.3Stages research sequence

The first stage is to to analyze the NPD, concurrent enginnering product development, and design manufacturing interface of Kesidang CNC 3D router. The researcher gather the information about Computer Numerical Control (CNC) 3d router that's related to the KESIDANG. In the first stage, the researcher provides the information about 3-axis CNC 3d router. All of the information is provided in the literature review.

The second stage is to study about the manpower ergonomic about KESIDANG. In this stage, the researcher collect data by using the RULA. The researcher takes the measurement of human body posture to gather the actual data when make installation of KESIDANG. Before that, researcher gather the predicted data by using the manikin in CATIA.

3.5 Quantitative Data

The quantitative data aims to achieve the objective of study the manpower ergonomic and time study during assembly Kesidang CNC 3D router. The data of human posture gather with time taken when assembly the KESIDANG will be collected. After that the data will be analyzed. The process begins with collect data of human body posture, time taken during assembly, analyze RULA, and simulation of working posture using CATIA (see Figure 3.4).

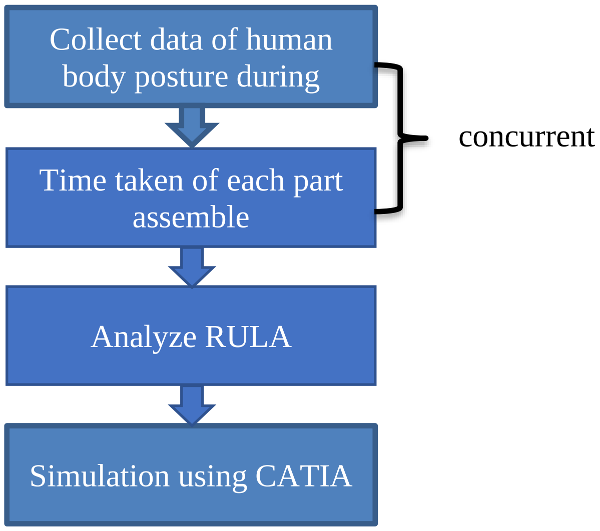


Figure 3.4procedure of quantitative data

3.5.1 Data Collection of Human Body Posture during assembly KESIDANG

Gather all the required information from the descriptions. Interpret each element of action as depicted in Figure 3.5 that constructs the working body posture correctly before translate them into score value.

Figure 3.5constructs the working body posture

Based on results obtained need required to evaluate and score using Figure 3.5 for each body region in section A for the arm and wrist, and section B for the neck and trunk. Then it is used to compile the risk factor variables, generating a single score that represents the level of MSD risk as depicted in Figure 3.6.

TASK NO.	RULA SCORE			
	PLACE	SCORE	TOTAL	IMPROVEMENT
D-3	UPPER ARM			
	LOWER ARM			
	WRIST			
	WRIST TWIST			
	POSTURE A			
	NECK			
	TRUNK			
	LEG			
	POSTURE B			
A1-32	UPPER ARM			
	LOWER ARM			
	WRIST			
	WRIST TWIST			
	POSTURE A			
	NECK			
	TRUNK			
	LEG			
	POSTURE B			
A1-33	UPPER ARM			
	LOWER ARM			
	WRIST			
	WRIST TWIST			
	POSTURE A			
	NECK			
	TRUNK			
	LEG			
	POSTURE B			

Figure 3.6 The risk factor score for posture A and B

3.5.2 Time Taken During Assembly KESIDANG

Typical lead times estimation is in the 4–5-month range. For each part of KESIDANG, the time taken will be recorded when assemble the frame (Figure 3.9), x-axis (Figure 3.10), y-axis (Figure 3.11), and z-axis (Figure 3.12). The stopwatch will be used to record the time (see in Figure 3.13). The time taken will be recorded in the table below (table 3.1)

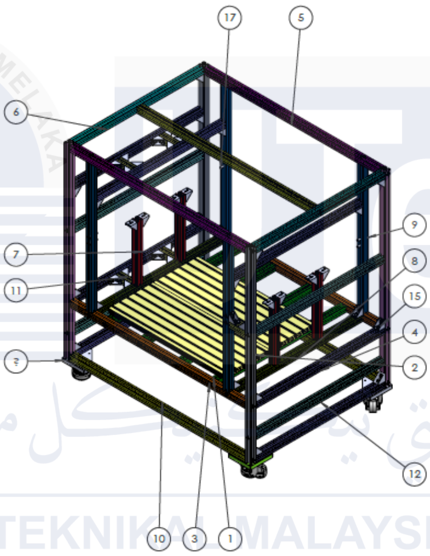


Figure 3.7Frame

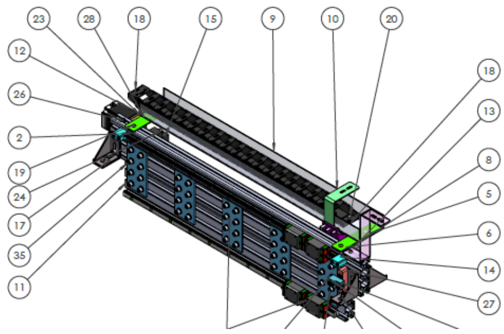


Figure 3.8X-axis

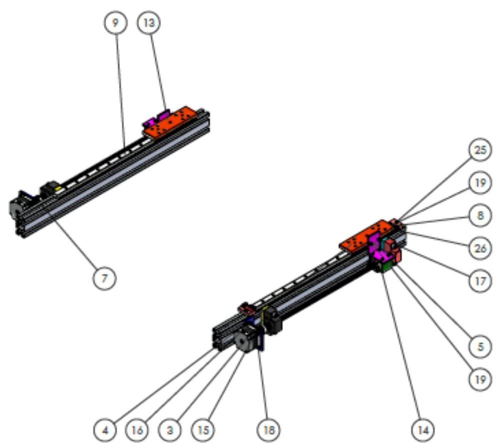


Figure 3.9 Y-axis

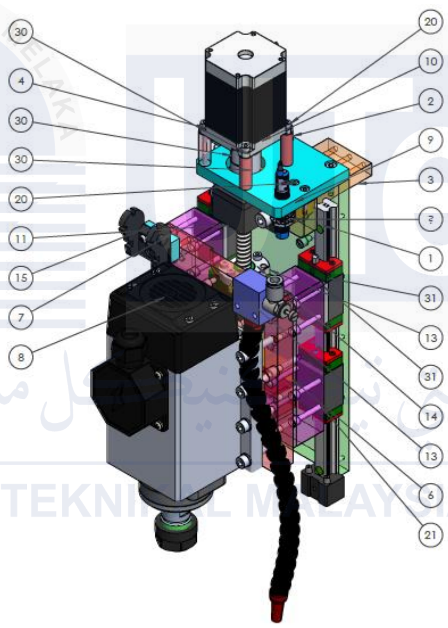


Figure 3.10 Z-axis

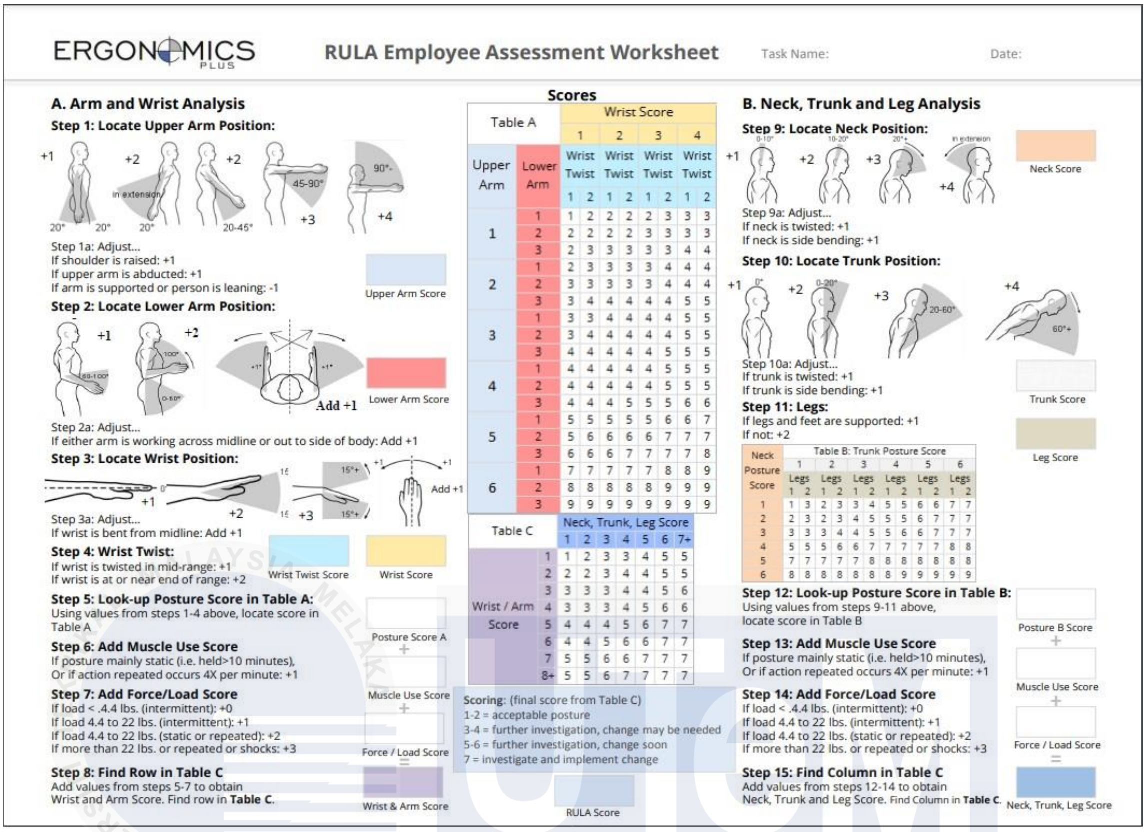
Figure 3.11 Stopwatch

Table 3.1 Table of time taken

NAME:		Date of study:					PIC.:
TIME STUDY (MAIN FRAME ASSEMBLY)		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
No.	Process Description	Time (min)					
		1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-1	Attached both V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30 to four V2_002_1000_01_MAIN BAR_00_PROFILE 30X30 and two V2_002_1000_08_BASE Z-AXIS MOUNT_00_PROFILE 30X30	134	69		67.67	74.43	89.32
A1-2	Insert the cap screw size M8 x 35	92	65		52.33	57.57	69.08
A1-3	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-4	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-5	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80
A1-6	Insert the cap screw size M8 x 35	30	23		17.67	19.43	23.32
A1-7	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-8	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-9	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80

3.5.3 Analyze RULA

The RULA Workers Assessment Worksheet is shown Figure 3.12. Segment B is used to analyse the neck, trunk, and legs, while segment A is used to analyse the upper and lower arm, wrist, and hand. With the help of the posture position diagram, each body part is independently scored.


ERGONOMICS PLUS

RULA Employee Assessment Worksheet

Task Name: Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 7: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

Table A		Wrist Score 1		Wrist Score 2		Wrist Score 3		Wrist Score 4	
Upper Arm	Lower Arm	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C		Neck, Trunk, Leg Score 1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score 1		2		3		4		5		6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 14: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

Figure 3.12 RULA Employee Assessment Worksheet

The outcome of the RULA assessment tool is the final RULA Score, which is a single score that quantifies the amount of MSD risk for the occupational task under review. The RULA score ranges from 1 to 7, with 7 being the highest possible. The chart below displays the RULA level of MSD risk descriptors and cut points (see in Figure 3.13).

Score	Level of MSD Risk
1-2	neglibible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

Figure 3.13 RULA Assessment Limitations

Posture	Left	Right	RULA score
1			7
2			7
3			6

Figure 3.14 RULA Analysis by using Catia

3.5.4 Simulation of Working Posture Using CATIA

A CAD programme called CATIA (Computer Aided Three-dimensional Interactive Application) is designed to improve ergonomic body posture in the industrial industry. CATIA users can create 3D models of items and workstations that can be used to assess and enhance the ergonomics of the design. By employing CATIA to create an ergonomically sound workplace, the organisation may reduce the risk of musculoskeletal illnesses and boost employee comfort and productivity. The creation of a manikin structure is the step depicted in Figure 3.15

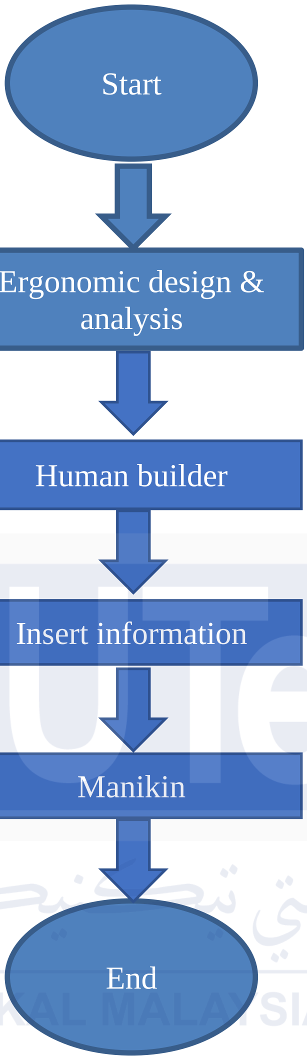


Figure 3.15 Flow to develop manikin structure

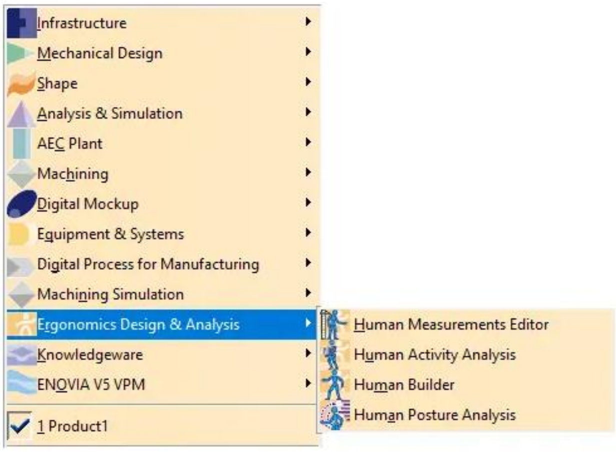


Figure 3.16 Ergonomics module on CATIA V5

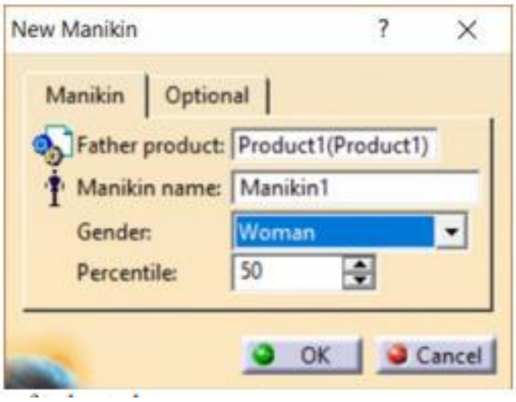


Figure 3.17 Manikin insertion for the study

3.6 Summary

In this chapter, the quantitatve data approach was used. The data collection of human body posture by uisng the RULA concurrent with time taken by using the stopwatch when assembly activities will be recorded into the table. The Osmond Ergonomic software will be used to analyze the data collection of RULA. Simulation of working posture by using the CATIA will be used to design the manikin structure of human body posture when assembly the KESIDANG.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses about the gathered data of actual result. Methode using the RULA as the primary tool to collect data of human body posture concurrent with time taken by using the stopwatch. The Osmond Ergonomic software used to analyzed the data of human body posture. Beside that, the used of CATIA actually to design the manikin posture of human body that related to actual posture when assembled the KESIDANG.

4.2 Actual Result

The actual result gets after make assembly for all sub assembly in Kesidang. The actual result of RULA for human body posture and time taken during assembly Kesidang CNC 3D Router.

4.2.1 RULA for human body posture

The ergonomics analysis in the process assembly KESIDANG CNC 3D Router based on CATIA used for the actual result.

Table 4.1 Main Frame RULA Posture

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-1	UPPER ARM	3	7	Investigate and change immediately	134s	69s		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
A1-2	UPPER ARM	3	5	Investigate further and change soon	92s	65s		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-3	UPPER ARM	2	4	Investigate further	197s	125s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

Table above show the data of RULA posture during installing the main frame. The total score for A1-1 got 7 means that harm to IV and should immediately improve to get suitable posture. The total score for A1-2 got 5 means that in a medium risk to IV and further investigation, change soon to get suitable posture. The total score for A1-3 got 4 means that in a low risk to IV and change may be needed to get suitable posture.

Table 4.2 X-Axis RULA Posture

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-1	UPPER ARM	3	3	Investigate further	27s	23		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	2						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-2	UPPER ARM	1	2	Acceptable	255	221		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-3	UPPER ARM	3	3	Investigate further	265	243		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						

Table above show the data of RULA posture during installing the X-axis. The total score for B-1 got 3 means that in a low risk to IV and change may be needed to get suitable posture.

The total score for B-2 got 2 means that the posture acceptable to IV and no need to change the posture. The total score for B-3 got 3 means that in a low risk to IV and change may be needed to get suitable posture.

Table 4.3 Y-Axis RULA Posture

TASK NO.	RULA SCORE PLACE	SCORE	TOTAL	IMPROVEMENT	TIME (s) 1st	2nd	ACTUAL PICTURE	SIMULATION
C (a)-1	UPPER ARM	2	3	Investigate further	39	33		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (a)-2	UPPER ARM	1	3	Investigate further	63	57		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (a)-3	UPPER ARM	1	6	Investigate further and change soon	79	62		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	SCORE B	6						

Table above show the data of RULA posture during installing the Y-axis. The total score for C(a)-1 got 3 means that in a low risk to IV and change may be needed to get suitable posture. The total score for C(a)-2 got 3 means that that in a low risk to IV and change may be needed to get suitable posture. The total score for C(a)-3 got 6 means that in a medium risk to IV and further investigation, change soon to get suitable posture.

Table 4.4 Z-Axis RULA Posture

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-1	UPPER ARM	1	6	Investigate further and change soon	843	743		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	SCORE B	6						
D-2	UPPER ARM	3	3	Investigate further	32	30		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	SCORE B	1						
D-3	UPPER ARM	3	3	Investigate further	25	19		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	SCORE B	1						

Table above show the data of RULA posture during installing the Z-axis. The total score for D-1 got 6 means that in a medium risk to IV and further investigation, change soon to get suitable posture. The total score for D-2 got 3 means that in a low risk to IV and change may be needed to get suitable posture. The total score for D-3 got 3 means that in a low risk to IV and change may be needed to get suitable posture.

4.2.2 Time study

The time taken during process assembly Kesidang CNC 3D Router by using the stopwatch used for the actual result. Aims to record the time for each work instruction when performing the installation of the KESIDANG. For the time recorded for both units, a graph can be produced. After that, normal time and standard time will be calculated after getting the average value.

Table 4.5 main frame

NAME:		Date of study:					PIC.:
TIME STUDY (MAIN FRAME ASSEMBLY)		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
		Time (min)					
No.	Process Description	1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-1	Attached both V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30 to four V2_002_1000_01_MAIN BAR_00_PROFILE 30X30 and two V2_002_1000_08_BASE Z-AXIS MOUNT_00_PROFILE 30X30	134	69		67.67	74.43	89.32
A1-2	Insert the cap screw size M8 x 35	92	65		52.33	57.57	69.08
A1-3	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-4	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-5	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80
A1-6	Insert the cap screw size M8 x 35	30	23		17.67	19.43	23.32
A1-7	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-8	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-9	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80

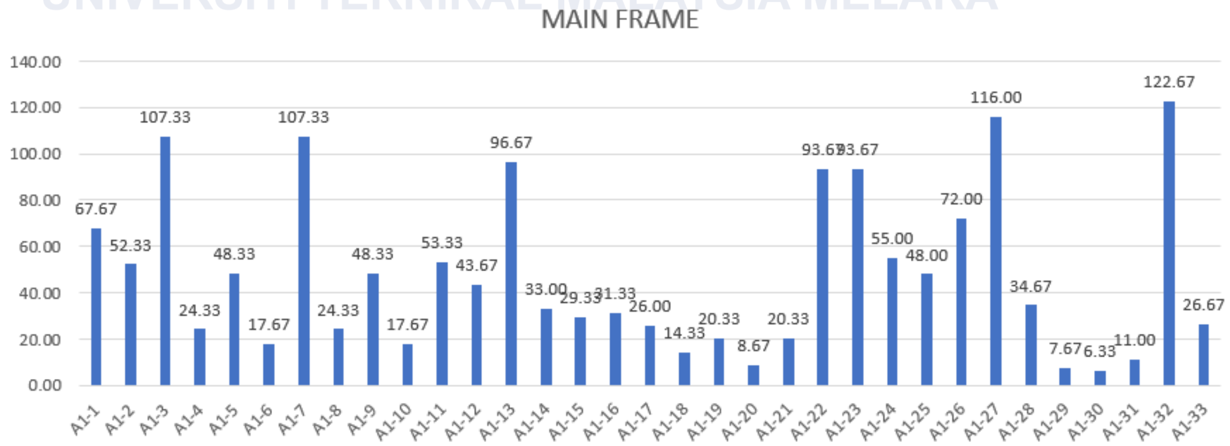


Figure 4.1Main Frame Graft

Normal time for A1-1:

Normal time = Average time x Rating factor

The rating factor for all labor is 1.1

= 67.67 x 1.1

= 74.43s

Standard time for A1-1:

Std time =Normal time x (1 + allowance factor)

The allowance factor for all labor is 0.2

=74.43 x (1 + 0.2)

= 89.32s

The graft can produce after getting the average of time for 1st and 2nd unit of KESIDANG. From the graft of main frame, A1-32 is the highest. This is because it takes a long time due to difficulties during installation and requires many steps. A1-30 is the lowest because it takes a short time due to little steps.

Table 4.6 Y-Axis

NAME:		Date of study:					PIC.:
TIME STUDY (RIGHT Y-AXIS ASSEMBLY)		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	Average	Normal time (Normal time = Average time x Rating factor)	Std Time (Std time =Normal time x (1 + allowance factor))
C (b)-1	Insert the CAP SCREWS M4x16 into the LINEAR RAIL and slide in the LINEAR RAIL into V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60.	31	25		18.67	20.53	24.64
C (b)-2	Measure the distance and adjust the position of LINEAR RAIL as per the drawing.	59	36		31.67	34.83	41.80
C (b)-3	Clamp V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and set up the Dial Gauge Indicator on the milling machine.	79	53		44.00	48.40	58.08
C (b)-4	Calibrate the position of the LINEAR RAIL on the V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and tighten the screws.	1335	1064		799.67	879.63	1055.56
C (b)-5	Attach V2_002_1200_01_MOTOR MOUNT_01_ALU on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with M5X10.	364	309		224.33	246.77	296.12
C (b)-6	Attach V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	383	319		234.00	257.40	308.88
C (b)-7	Attach V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	25	19		14.67	16.13	19.36
C (b)-8	Attach UPPER BALL SCREW END MOUNT on the V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) with CAP SCREW M8X35.	101	86		62.33	68.57	82.28
C (b)-9	Attach BLOCK to SFU-1204 with M4X16.	32	29		20.33	22.37	26.84

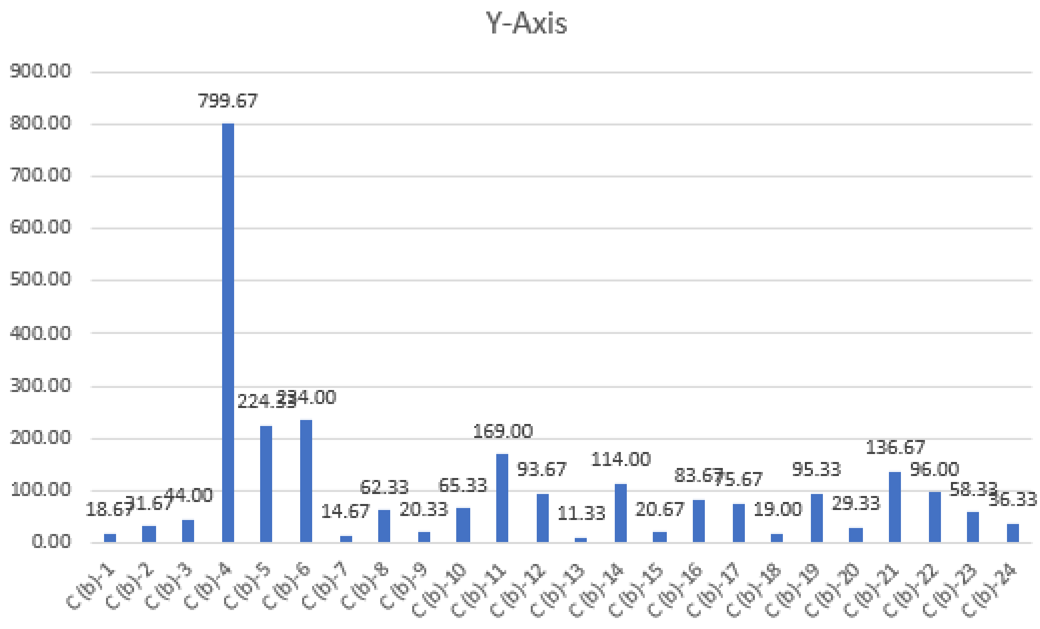


Figure 4.2Y-Axis Graft

Normal time for C(b)-1:

Normal time = Average time x Rating factor

The rating factor for all labor is 1.1

= 18.67 x 1.1

= 20.53s

Standard time for C(b)-1:

Std time = Normal time x (1 + allowance factor)

The allowance factor for all labor is 0.2

= 20.53 x (1 + 0.2)

= 24.64s

The graft can produce after getting the average of time for 1st and 2nd unit of KESIDANG. From the y-axis graft, C(b)-4 is the highest. This is because it takes a long time due to difficulties during installation and requires many steps. C(b)-13 is the lowest because it takes a short time due to little steps.

\

Table 4.7 X-Axis

NAME: TIME STUDY (X-AXIS ASSEMBLY)		Date of study: Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			PIC.: Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
B-1	Attach V2_002_1300_01_X-AXIS MAIN BAR and V2_002_1300_11_X-AXIS LOWER BAR with distance 47.5MM from the end of MAIN BAR.	27	23		16.67	18.33	22.00
B-2	Attach PROFILE LINK PLATE at left on the assembly BAR 9.5mm from end of LOWER BAR. Attach spring washer M6 and tight using Cap Screw M6x16.	255	221		158.67	174.53	209.44
B-3	With the distance between the plates 87.5MM attach another PROFILE LINK PLATE. Put spring washer M6 and tight using Cap Screw M6x16.	265	243		169.33	186.27	223.52
B-4	Repeat the process with another 3 PROFILE LINK PLATE.	1222	1091		771.00	848.10	1017.72
B-5	Rotate the assembly BAR. Attach PROFILE LINK PLATE at the left side with distance 59MM from the end of LOWER BAR. Attach spring washer M6 and tight with Cap Screw M6x16.	420	362		260.67	286.73	344.08
B-6	Repeat the process with another 2 PROFILE LINK PLATE with distance between plate is 190MM.	267	243		170.00	187.00	224.40
B-7	Place RAIL on top of the V2_002_1300_01_X-AXIS MAIN	366	322		229.33	252.27	302.72
B-8	At the left side the distance between RAIL and end of MAIN	276	243		173.00	190.30	228.36

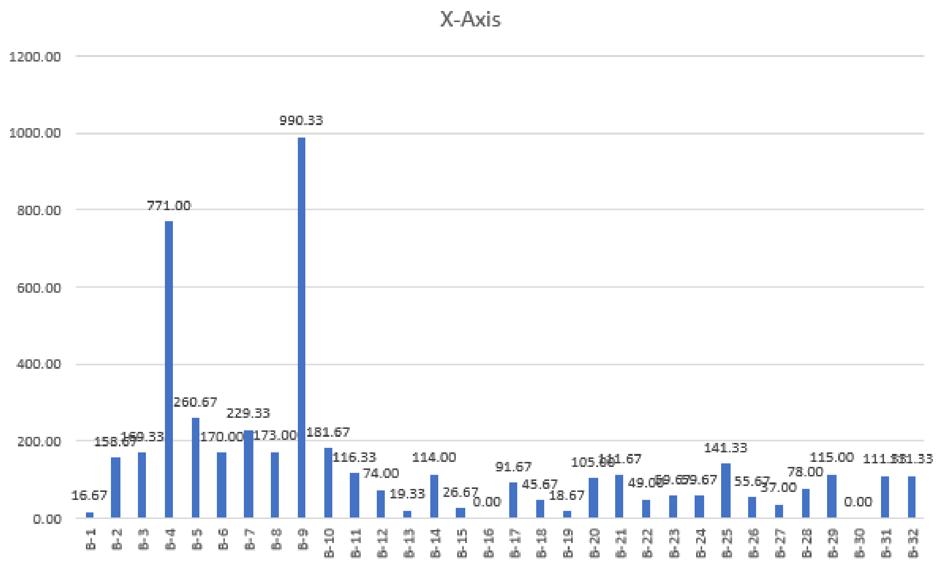


Figure 4.3X-Axis Graft

Normal time for B-1:

Normal time = Average time x Rating factor

The rating factor for all labor is 1.1

= 16.67 x 1.1

= 18.33s

Standard time for B-1:

Std time = Normal time x (1 + allowance factor)

The allowance factor for all labor is 0.2

= 18.33 x (1 + 0.2)

= 22s

The graft can produce after getting the average of time for 1st and 2nd unit of KESIDANG. From the x-axis graft, B-9 is the highest. This is because it takes a long time due to difficulties during installation and requires many steps. B-1 is the lowest because it takes a short time due to little steps. B-16 and B-30 zero value because doesn't have step during the installation.

Table 4.8 Z-Axis

NAME: TIME STUDY (Z-AXIS ASSEMBLY)		Date of study: Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			PIC.: Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
D-1	calibrate linear rail for the Z-axis	843	743		528.67	581.53	697.84
D-2	attach the V2_002_1400_05_SPACER PLATE_00_ALU to the bottom V2_002_1400_01_MAIN PLATE_00_ALU	32	30		20.67	22.73	27.28
D-3	attach EF10_5 BLOCK to the V2_002_1400_05_SPACER PLATE_00_ALU	25	19		14.67	16.13	19.36
D-4	use the cap screw M8x50	74	56		43.33	47.67	57.2
D-5	insert the Ballscrew through the Block	146	135		93.67	103.03	123.64
D-6	insert the Ball Nut through the Ballscrew and attach it with the Block	354	309		221.00	243.10	291.72
D-7	use the cap screw M4x16	72	59		43.67	48.03	57.64
D-8	insert the ek10 BLOCK to the Ballscrew	208	176		128.00	140.80	168.96
D-9	attach the V2_002_1400_05_SPACER PLATE_00_ALU to the top V2_002_1400_01_MAIN PLATE_00_ALU	245	215		153.33	168.67	202.4
D-10	attach the ek10 BLOCK to the V2_002_1400_05_SPACER PLATE_00_ALU	149	128		92.33	101.57	121.88
D-11	use the cap screw M8x50	37	22		19.67	21.63	25.96
D-12	attach the V2_002_1400_02_TOP PLATE_01_ALU to the V2_002_1400_01_MAIN PLATE_00_ALU	103	91		64.67	71.13	85.36

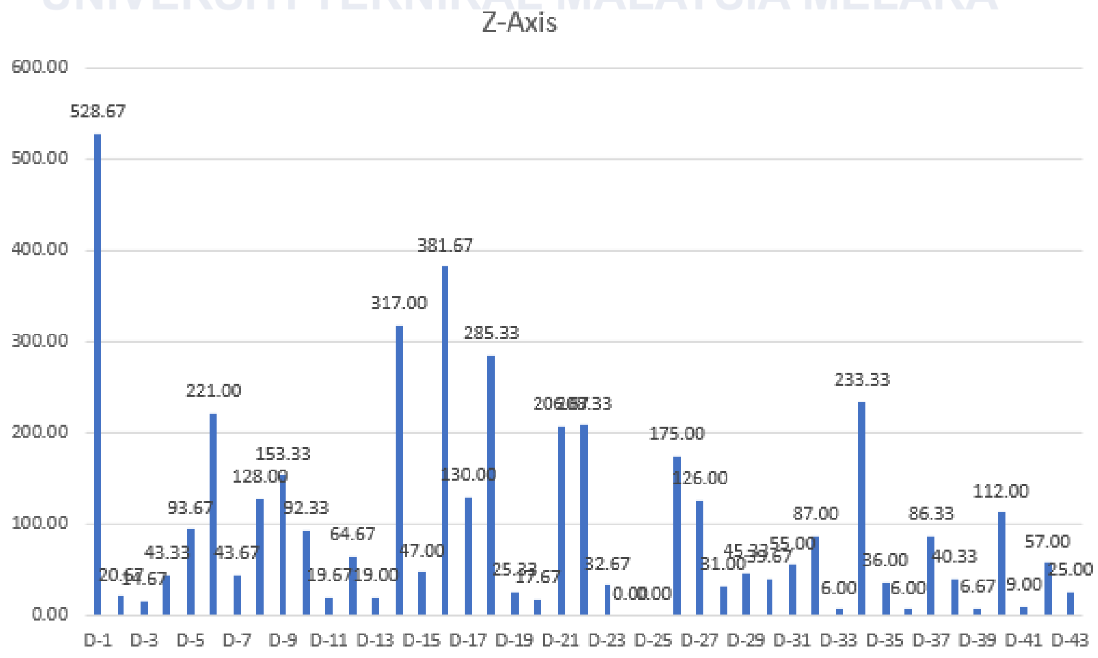


Figure 4.4 Z-Axis Graft

Normal time for D-1:

Normal time = Average time x Rating factor

= 528.67 x 1.1

= 581.53s

The rating factor for all labor is 1.1

Standard time for D-1:

Std time = Normal time x (1 + allowance factor)

= 581.53 x (1 + 0.2)

= 697.84s

The allowance factor for all labor is 0.2

The graft can produce after getting the average of time for 1st and 2nd unit of KESIDANG. From the z-axis graft, D-1 is the highest. This is because it takes a long time due to difficulties during installation and requires many steps. D-33 and D-36 is the lowest because it takes a short time due to little steps. D-24 and D-25 zero value because doesn't have step during the installation.

process	Total average	total normal time	total standard time
main frame	1579.67	1737.63	2085.16
y axis right	2554.00	2809.40	3371.28
y axis left	2604.00	2864.40	3437.28
x axis	4661.67	5127.83	6153.40
z axis	4271.00	4698.10	5637.72

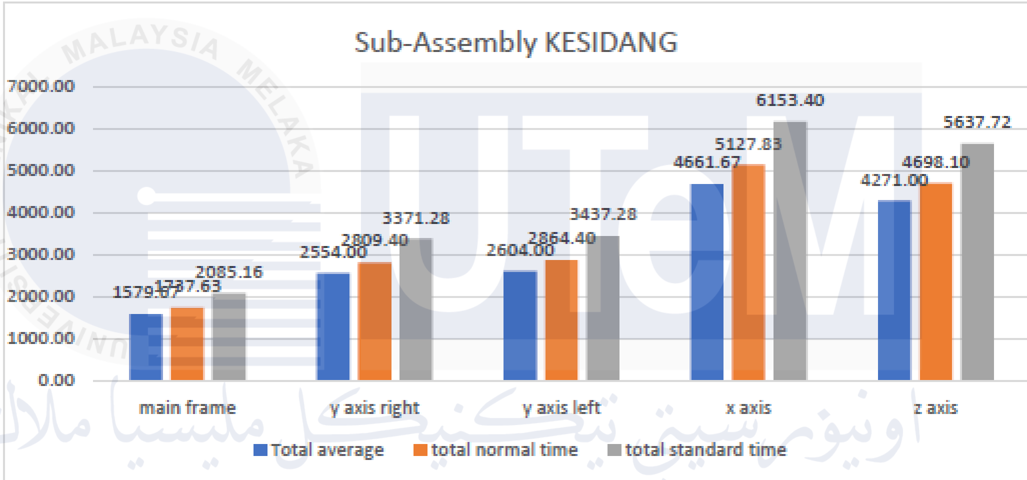


Figure 4.5 Overall Graft

From the graft overall of sub-assembly KESIDANG, the x-axis graft of total average, total normal time and total standard time is the highest. This is because x-axis has many parts and need more step to assemble. Main frame is the lowest compare to the others sub-assembly because main frame has a little part and no need more step to assemble.

4.2.3 Improvement of human body posture

The improvement makes in RULA of human body posture to overcome the problem that happened during assembly KESIDANG CNC 3D Router.

Table 4.9 Improvement of Human Body Posture

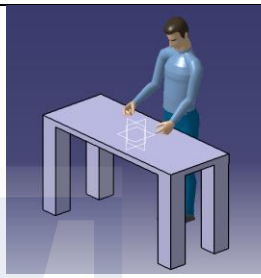
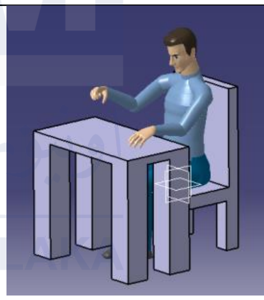
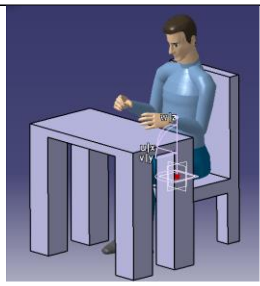
Task no.	Rula score			Actual picture	Simulation	New simulation	Comment
	place	score	total				
A1-1	upper arm	3	7				Investigate further
	lower arm	3					
	wrist	3					
	wrist twist	1					
	posture a	4					
	neck	4					
	trunk	3					
	leg	1					
	posture b	6					
B-12	upper arm	3	5				Investigate further
	lower arm	3					
	wrist	3					
	wrist twist	1					
	posture a	4					
	neck	1					
	trunk	4					
	leg	1					
	posture b	5					
C (b)-1	upper arm	2	3				Acceptable
	lower arm	2					
	wrist	1					
	wrist twist	1					
	posture a	3					
	neck	2					
	trunk	2					
	leg	1					
	posture b	2					

Table 4.11 show the human body posture before and after improvement. Before the improvement, we can see that some of the worker posture during assembly the KESIDANG CNC 3D Router are not suitable during installation is carried out.

For the example, when attach length bar to main bar and Z-axis mount does not have any support to the body or worktable during assembly the main frame. This will cause the worker's body to be hurt or injured and take a long time to finish the process assemble due to non-ergonomic body posture. After putting the table, we can see the human body posture from RULA analysis give a yellow color mean that in low risk. This can help worker in comfortable work during process assembly. Long periods of time can also be shortened when working with a comfortable body posture.

When Place Linear Rail on the Aluminum Profile with T-nuts and Cap Screws in standing posture during assembly the Y-axis, we can see that it gives low risk but can make worker feel tired if stay on standing posture for a long time even though the table has been set. This also can make the production not running perfectly. After putting the chair, we can see the human body posture from RULA analysis give a green color mean that the posture is acceptable and negligible risk.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The study findings, achievements, and contributions to knowledge are assessed in this chapter. Future research endeavours about the time study of KESIDANG assembly and the ergonomic positioning of the human body during KESIDANG CNC 3D router assembly are also discussed.

5.2 Conclusion

Finally, the study's objective has been achieved. Design manufacturing interface is critical for product development especially for time study and ergonomic human body posture during assembly KESIDANG CNC 3D Router for main frame, X-axis, Y-axis, and Z-axis. This thesis contributes to the collection of data about KESIDANG CNC 3D Router which will help students to continue the next study about its installation and also help Teaching Factory to produce the next machine production. The production of the first KESIDANG machine can be seen the difference with the second machine after the installation is done. the difference in terms of time taken by the second machine is shorter than the installation of the first machine when improvements are made. This can strengthen and improve the development process and ensure that project goals are achieved as best as possible.

5.3 Recommendation

Other options that can be used for the data collection process for KESIDANG CNC 3D Router assembly should be further investigated. In addition, the method of collecting data related to human body posture during installation needs to be investigated further in order to be able to collect data accurately for analysis. It may be the objective of the project to improve the way of taking the time more accurately as well as getting the body position data more perfectly. In addition, since this study is still in its early stages, it is possible that there will be follow-up studies in the future.

REFERENCES

Aktan, M. E., Akkuş, N., Yilmaz, A., & Akdoğan, E. (2016). Design and implementation of 3 Axis CNC router for computer aided manufacturing courses. *MATEC Web of Conferences*, *45*. https://doi.org/10.1051/matecconf/20164505002

Barnes, C. J., Dalgleish, G. F., Jared, G. E. M., Swift, K. G., & Tate, S. J. (1997). Assembly sequence structures in design for assembly. *Proceedings of the IEEE International Symposium on Assembly and Task Planning*, 164–169. https://doi.org/10.1109/isatp.1997.615402

Budiman, I., Sembiring, A. C., Tampubolon, J., Wahyuni, D., & Dharmala, A. (2019). Improving effectiveness and efficiency of assembly line with a stopwatch time study and balancing activity elements. *Journal of Physics: Conference Series, 1230*(1). https://doi.org/10.1088/1742-6596/1230/1/012041

Business, G., & Research, M. (2017). Time Study Analysis to Find Normal Time Workforce Scheduling ILO Standard Time: Case Study of Parking Pay Station Bandung Electronic Center TIME STUDY ANALYSIS TO FIND NORMAL TIME WORKFORCE SCHEDULING ILO STANDARD TIME Study Case: Parking Pay Station Bandung Electronic Center. In *An International Journal* (Vol. 10, Issue 4s). https://www.researchgate.net/publication/336126768

Dongre, A. U., Kumar Jha, B., Aachat, P. S., & Patil, V. R. (2017). Concurrent Engineering: A Review. *International Research Journal of Engineering and Technology*. www.irjet.net

Ginting, R., Hadiyoso, S., & Aulia, S. (2017). Implementation 3-Axis CNC Router for Small Scale Industry. In *International Journal of Applied Engineering Research* (Vol. 12). http://www.ripublication.com

Hambali, A., Sapuan, S. M., Ismail, N., Nukman, Y., & Karim, M. S. A. (2009). The Important Role of Concurrent Engineering in Product Development Process. In *Pertanika J. Sci. & Technol* (Vol. 17, Issue 1).

Huang, C., & Shi, D. (2022). Research on Application of 3D Simulation Technology in Industrial Product Design Technology. *Advances in Multimedia*, *2022*. https://doi.org/10.1155/2022/3581886

Liang, D., Sun, G. Z., & Wu, S. (n.d.). *The Ergonomics Analysis In the Process of Reversed Loader Cylinder Virtual Assembly Based on CATIA and DELMIA*. https://doi.org/10.1051/C

Najy, R. J. (2013). The role of computer aided design (CAD) in the manufacturing and digital control (CAM). *Contemporary Engineering Sciences*, *6*(5–8), 297–312. https://doi.org/10.12988/ces.2013.3736

Saif, U., Guan, Z., Wang, B., Mirza, J., & Huang, S. (2014). A survey on assembly lines and its types. In *Frontiers of Mechanical Engineering* (Vol. 9, Issue 2, pp. 95–105). Higher Education Press. https://doi.org/10.1007/s11465-014-0302-1

Singh, S. (2013). Anthropometric Measurements and Body Composition Parameters of Farm Women in North Gujarat. *Journal of Ergonomics*, *03*(01). https://doi.org/10.4172/2165-7556.1000114

Sluchak, T. J. (n.d.). *Ergonomics Origins, Focus, and Implementation Considerations*.

Taherdoost, H. (2021). Data Collection Methods and Tools for Research; A Step-by-Step Guide to Choose Data Collection Technique for Academic and Business Research Projects Hamed Taherdoost. Data Collection Methods and Tools for Research; A Step-by-Step Guide to Choose Data Collection Technique for Academic Data Collection Methods and Tools for Research; A Step-by-Step Guide to Choose Data Collection Technique for Academic and Business Research Projects. In *International*

Journal of Academic Research in Management (IJARM) (Vol. 2021, Issue 1). https://hal.science/hal-03741847

Yusuf, M., Adiputra, N., Sutjana, I. D. P., & Tirtayasa, K. (2016). The Improvement of Work Posture Using RULA (Rapid Upper Limb Assessment) Analysis to Decrease Subjective Disorders of Strawberry Farmers in Bali. *International Research Journal of Engineering, IT & Scientific Research*, *2*(9), 1. https://doi.org/10.21744/irjeis.v2i9.163

Adiatmika I P G, A. Manuaba, N. Adiputra, D.P. Sutjana. 2007. Perbaikan Kondisi Kerja Dengan Pendekatan Ergonomic Total Menurunkan Keluhan Muskuloskeletal Dan Kelelahan Serta Meningkatkan Produktivitas Dan Penghasilan Perajin Pengecatan Logam Di Kediri-Tabanan. Indonesian Journal Of Biomedical Science. Vol. 1, No. 3 Desember 2007.

Adiputra, N, Sutjana D.P. & Manuaba, A. 2000. Ergonomicss Intervention in Small Scale Industry in Bali. Dalam : Lim, KY ed. Proceding of the Joint Conference of APCHI and ASEAN Ergonomics, Singapore.

Armstrong TJ (1983) An Ergonomics Guide to Carpal Tunnel Syndrome. American Industrial Hygiene Association. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

B. Jayachandraiah, O. V. Krishna, P. A. Khan, and R. A. Reddy., 2014, "Fabrication of Low Cost 3-*Axis* Cnc Router," *Int. J. Eng. Sci. Invent.*, vol. 3, no. 6, pp. 1–10. https://www.ripublication.com/ijaer17/ijaerv12n17_34.pdf

Bicheno,J.(1994) *The Quality 50: a guide gurus, tools, waste, techniques and system,* PICSIE Books.

Bhuiyan, N., Thoms on, V. and Gerwin, D. (2006). Implementing concurrent engineering, *Journal of Research Technology Management*, *49*(1), 38-43.

Cohen, L. (1995) *Quality function deployment – How to make QFD work for you,* Addison Wesly Longman Inc., USA.

Chase, R.B., Aquilano, N.J and Jacobs, F.R. (1998). *Production and Operations Management – Manufacturing and Services, , Irwin* 8th edn, Irwin/McGraw-Hill.

Dean, E.B. (1998) *Quality function deployment: From the perspective of competitive advantage*. Available at: *http://akao.larc.nasa.gov/dfc/qfd.html,4pages*.

David Juarez, Jesus Segui, Ana Mengual, Santiago Ferrandiz, Application of Concurrent engineering in product and process design, annals of the university of
oradea, Issue 3, 2015
https://www.academia.edu/download/53592065/IRJET-V4I5698.pdf

D. Mourtzis, "3D simulation in the design and operation ofmanufacturing systems: state of the art and new trends," *International Journal of Production Research*, vol. 58, no. 3, pp. 1–23, 2019.

Douglas Bryden, CAD and Rapid Prototyping for Product Design (Laurence King Publishing 2014)

Eastman-Kodak. (1983). *Ergonomic Design for People at Work: Vollllle I.* Belmont, CA: Lifetime Learning Publications.
https://journals.sagepub.com/doi/pdf/10.1177/216507999204000302

Evans, J.R. (1996). *Applied Production and Operations Management,* 4th edn, West.

Evans, Jamses.R. "Production / Operations Management: Quality, Performance,
and Value" 5 Th Ed, USA: West Publishing Company, 1997.

Frechtling, J. (2002). An overview of quantitative and qualitative data collection methods The 2002 user-friendly handbook for project evaluation (pp. 43-62).

Febriana, N. V., Lestari, E. R., & Anggraini, S. (2015). Analisis Pengukuran Waktu Kerja Dengan Metode Pengukuran Kerja Secara Tidak Langsung Pada Bagian Pengemasan di PT JAPFA COMFEED INDONESIA Tbk. *Jurnal Industri*, **4**, 66-73.

Gite LP, Yadav BG (1989) Anthropometric survey for agricultural machinery design: An Indian case study. Appl Ergon 20: 191-196. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Gupta PK, Sharma AP, Gupta ML (1983) Anthropometrc survey of Indian farm workers. Agricultural Mechanisation in Asia, Africa and Laitn America 14: 27- 30.\ https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Ghozali, M. W., & Hermansyah, M. (2016). Pengukuran Waktu Baku Proses Finishing Line Volpak Produksi Lannate SP 25 Gram Philipina Guna Meningkatkan Produktivitas (PT. Dupont Agricultural Products Indonesia). Journal Knowledge Industrial Engineering (JKIE)

G. Boothroyd. Product Design For Manufacture And Assembly. *Computer-Aided Design*, 26(9):505-520, 1994.

Hong-Chao Zhang, 1994, "Manufacturing Process Planning". Texas Tech University *Researchgate | Find and Share Research*, www.researchgate.net/profile/Hong-Chao-Zhang/publication/284188843_Manufacturing_Process_Planning/links/564f766008aeafc2aab3dc25/Manufacturing-Process-Planning.pdf?origin=publication_detail. Accessed 2 May 2023.

Haik, Yousef, et al. Engineering Design Process. Cengage Learning, 2018.

Jack Zhou, Shlomo Carmi, Alan Lau, and Spiros Koulas, Concurrent Engineering Concepts Applied to Concurrent Education and Research, International Conference on Concurrent Engineering, Research and Applications (CE96/ISPE), August 1996.
https://www.academia.edu/download/53592065/IRJET-V4I5698.pdf

J.P. Womack, D.T. Jones, D. Roos, The Machine that Changed the World
MIT Rawson Associates, 1990.
https://www.sciencedirect.com/science/article/pii/S000785060763251X

K.T. Ulrich and S.D. Eppinger, *Product Design and Development*. 5th edition.
New York: McGraw Hill, 2012.

Kabir, S. M. S. (2016). Methods Of Data Collection Basic Guidelines for Research: An Introductory Approach for All Disciplines (first ed., pp. 201-275).

Krajewski, Lee J & Ritzman, Larry P. "Operations Management: Strategy and
Analysis" 6th Ed New Jersey, 2002.

Kalkowska, J., Trzc ieliniski, S. and Wlodarkiewicz -Klimek, H. (2005). Investigation of concurrent engineering in Polish manufacturing companies -some results of pilot research. *Fifth International Workshop on Robot Motion and Control* (p. 315-319). Poland.

Liu, M., Lai, J., & Shen, W. (2014). A method for transformation of engineering bill of materials to maintenance bill of materials. *Robotics and Computer-Integrated Manufacturing*, *30*(2), 142–149. https://doi.org/10.1016/j.rcim.2013.09.008
McMahon, C., and Browne, J. (1993). *CADCAM – From Principles to Practice*, Addison-Wesley.

M.E.Merchant Important Trends in the International Development of Manufacturing Systems Science and Technology. proceedings of the ClRPManufacturing Systems Vol 19/1 p5-12 https://www.sciencedirect.com/science/article/pii/S000785060763251X

Menks, D., Ahmed, A. and Fu, K. (2000) *Quality function deployment, SENG613 Team Work*, Software Engineering Research Network, University of Galgary, Fourth of December, Available at: *http://sern.ucalgary.cal-kifu/courses/SENG613/teamwork.html.*

Mather H. Competitive manufacturing. Prentice Hall, Englewood Cliffs, NJ, 1989

Olsen, W. (2012). Data collection: Key debates and methods in social research (Vol. 1): Sage.

Paulo, Rogério, and Maria., 2010, "Prototype CNC Machine Design," International Conference on Industry Applications. https://www.ripublication.com/ijaer17/ijaerv12n17_34.pdf

Portioli-Staudacher, A., *et, al.*, (2003), 'Implementation of Concurrent Engineering: a survey in Italy and Belguim. https://www.iaeng.org/publication/WCECS2011/WCECS2011_pp1074-1080.pdf

Pradu-Lu JLD (2007) Anthropometric measurement of Filipino manufacturing workers. International Journal of Industrial Ergonomics 37: 497-503. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Philip GS, Tewari VK (2000) Anthropometry of Indian female agricultural workers and implication on tool design. Agric Mech Asia Afr Lat Am 31: 63-66. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Peng Yong, Gong Jian-xing, Huang Ke-di. Research on Reuse-oriented similar- ity evaluation of BOM conceptual model. Journal of National University of Defense Technology 2011;33(2).

Pine B J. Mass customization: The new frontier in business competition. Harvard Business School Press, Boston, Mass, 1993

Ray GG, Ghosh S, Atreya V (1995) An anthropometric survey of Indian schoolchildren aged 3-5 years. Appl Ergon 26: 67-72. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Rully, T., & Rahmawati, N. T. (2015). Perencanaan Pengukuran kerja Dalam Menentukan Waktu Standar Dengan Metode Time Study Guna Meningkatkan Produktivitas Kerja Pada Divisi Pompa Minyak Bukaka Teknik Utama Tbk. *Jurnal Ilmiah Manajemen Fakultas Ekonomi*, **1**, 12-18.

Sen RN, Nag PK, Ray GG (2003) Some anthropometry of the people of Eastern India. J Indian Anthrop 12: 201-208. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Shtub A, Dar-El E M. A methodology for the selection of assembly systems. International Journal of Production Research, 1989, 27(1): 175–186

Sapuan, S.M., Osma n, M.R. and Nukma n, Y. (2006). State of the art of the concurrent techniques in the automotive industry. *Journal of Engineering Design*, *17*(2), 143-157.

Singh, S. (2013). Anthropometric Measurements and Body Composition Parameters of Farm Women in North Gujarat. *Journal of Ergonomics*, *03*(01). https://doi.org/10.4172/2165-7556.1000114

Tewari VK (2004) Ergonomic database for engineering design of agricultural machines. Final Report. https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Urban T L, Chiang W C. An optimal piecewise-linear program for the U-line balancing problem with stochastic task times. European Journal of Operational Research, 2006, 168(3): 109–120

Yassine, A., and Braha, D., (2003), ‘Concurrent Engineering: Research and Applications, Four Complex concurrent engineering and the design structure matrix method ’. *Sage Publications*, Vol. 11, No. 3, pp. 165-176.
https://www.iaeng.org/publication/WCECS2011/WCECS2011_pp1074-1080.pdf

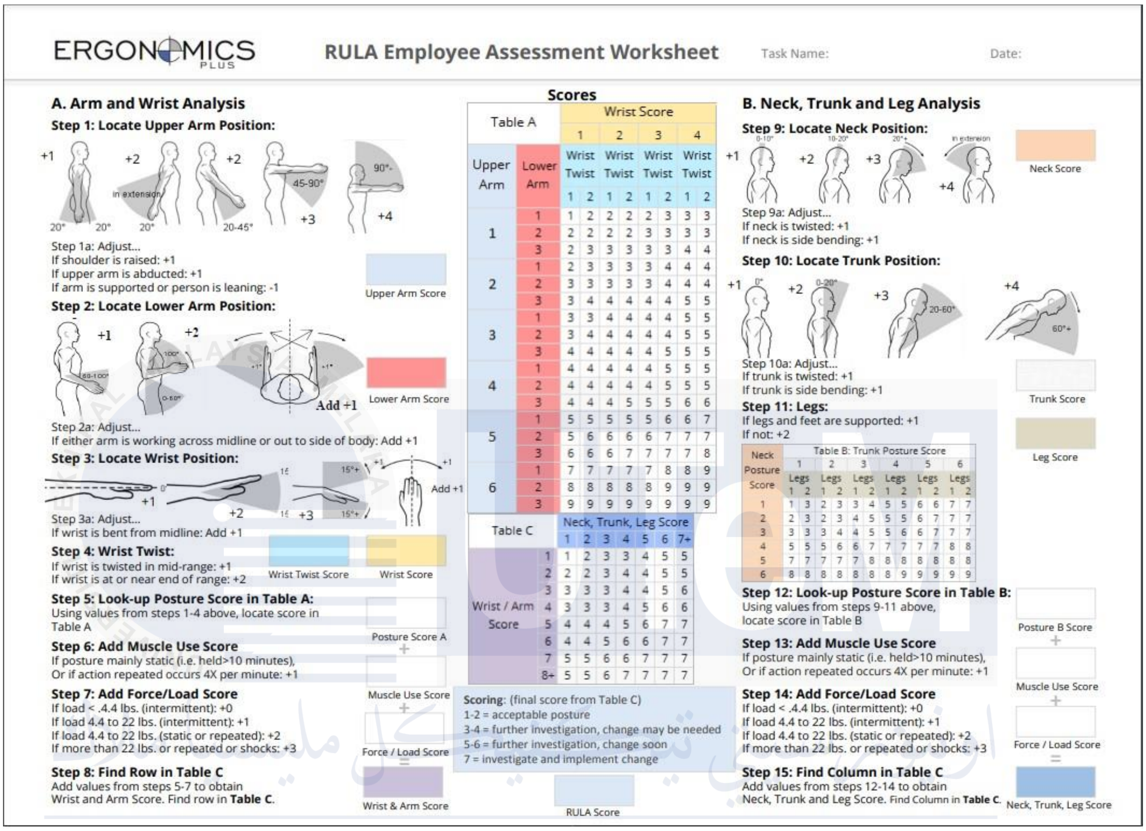
Yanjun Qian, Jun Lin, Recent Advances in Concurrent Engineering Modeling, 5th International Asia Conference on Industrial Engineering and Management Innovation (IEMI 2014), pp.6-9, 2014
https://www.academia.edu/download/53592065/IRJET-V4I5698.pdf

Yadav R, Tewari VK, Prasad N (1997) Anthropometric data of Indian farm workers--a module analysis. Appl Ergon 28: 69-71.
https://books.google.com/books?hl=en&lr=&id=nwfvSbuyBdMC&oi=fnd&pg=PA1&dq=anthropometry&ots=c9m-CJk4DP&sig=eElxSlPwtZZXSHBMgYWQhTJJT_I

Yin, C., & Zhang, W. (2021). New Product Development Process Models. *Proceedings - 2021 International Conference on E-Commerce and E-Management*, *ICECEM 2021*, 240–243. https://doi.org/10.1109/ICECEM54757.2021.00054

APPENDICES

APPENDIX A RULA Employee Assessment Worksheet



ERGONOMICS PLUS

RULA Employee Assessment Worksheet

Task Name:

Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

Table A		Wrist Score 1		Wrist Score 2		Wrist Score 3		Wrist Score 4	
Upper Arm	Lower Arm	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C	Neck, Trunk, Leg Score 1	2	3	4	5	6	7+
Wrist / Arm Score 1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score 1, Legs 1	1, Legs 2	2, Legs 1	2, Legs 2	3, Legs 1	3, Legs 2	4, Legs 1	4, Legs 2	5, Legs 1	5, Legs 2	6, Legs 1	6, Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

APPENDIX B Gantt Chart

PSM 1

No	Project Activity	WEEK												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	PSM briefing													
2	meeting with intern student & SV													
3	Chapter 1: Introduction													
4	history about KESIDANG													
5	Chapter 2: NPD and DMI													
6	Chapter 2:CE and ergonomics													
7	methodology briefing													
8	second meeting with SV													
9	Chapter 3: methodology													
10	third meeting with SV													
11	Chapter 3 : complete chapter 3													
12	Chapter 4 : expected result													
13	Chapter 4 : complete chapter 4													
14	draft submission (C1 & C2)													
15	draft submission (C3 & C4)													
16	submit report & logbook													
17	presentation													

PSM 1

PROJECT ACTIVITY	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Research and Literature Review:														
Breafing About PSM 2		■												
First Meeting with SV			■											
Additional Research				■										
Second Meeting with SV							■							
Chapter 1: Title, Objective, and Problem Statement										■				
Breafing About submission PSM2												■		
Scope Project:														
Chapter 2: Data Research				■										
Assemble KESIDANG	■	■	■	■	■	■	■							
Chapter 4: Data Collection	■	■	■	■	■	■	■							
Produce Graft from Time Study Table								■						
Analyze Finding						■	■	■						
Chapter 3: Research Methodology									■					
Report Writing:														
Chapter 4: Actual Result						■	■	■						
Chapter 5: Conclusion and Recommendation									■					
Finalize Report Chapter 1-5									■					
Submit Draft of Chapter 4 & 5 to SV											■			
Summary 4-Page											■	■		
Logbook												■		
Submit Report, 4-Pages Summary, and Logbook													■	
Making Poster													■	
Presentation														■

APPENDIX C Time Study

MAIN FRAME

NAME: TIME STUDY (MAIN FRAME ASSEMBLY)		Date of study: Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			PIC.: Approved By:
		Time (min)					
No.	Process Description	1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-1	Attached both V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30 to four V2_002_1000_01_MAIN BAR_00_PROFILE 30X30 and two V2_002_1000_08_BASE Z-AXIS MOUNT_00_PROFILE 30X30	134	69		67.67	74.43	89.32
A1-2	Insert the cap screw size M8 x 35	92	65		52.33	57.57	69.08
A1-3	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-4	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-5	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80
A1-6	Insert the cap screw size M8 x 35	30	23		17.67	19.43	23.32
A1-7	Attached both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30 and two V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	197	125		107.33	118.07	141.68
A1-8	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	43	30		24.33	26.77	32.12
A1-9	Add two V2_002_1000_12_Y-AXIS CENTER_00_PROFILE 30X30 to both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	83	62		48.33	53.17	63.80

No.	Process Description	Time (min)					
		1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-10	Insert the cap screw size M8 x 35	30	23		17.67	19.43	23.32
A1-11	Attached each edge V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30	92	68		53.33	58.67	70.40
A1-12	Insert the cap screw size M8 x 35	72	59		43.67	48.03	57.64
A1-13	Add two V2_002_1000_11_CENTER SUPPORT_00_PROFILE 30X30 in between both V2_002_1000_08_BASE Z-AXIS MOUNT_00_PROFILE 30X30 and V2_002_1000_04_WIDE BAR_00_PROFILE 30X30	154	136		96.67	106.33	127.60
A1-14	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	56	43		33.00	36.30	43.56
A1-15	Attached each edge V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 to V2_002_1000_05_TOP LENGTH BAR_00_PROFILE 30X30	46	42		29.33	32.27	38.72
A1-16	Insert the cap screw size M8 x 35	51	43		31.33	34.47	41.36
A1-17	Add V2_002_1000_10_CENTER LAMP BAR_00_PROFILE 30X30 to V2_002_1000_06_TOP WIDE BAR_00_PROFILE 30X30	53	25		26.00	28.60	34.32
A1-18	Insert the cap screw size M8 x 35	25	18		14.33	15.77	18.92
A1-19	Add four V2_002_1000_09_Z-AXIS MOUNT_00_PROFILE 30X30 to V2_002_1000_05_TOP LENGTH BAR_00_PROFILE 30X30	37	24		20.33	22.37	26.84

No.	Process Description	Time (min)					
		1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-20	Insert the cap screw size M8 x 35	16	10		8.67	9.53	11.44
A1-21	Add four V2_002_1000_09_Z-AXIS MOUNT_00_PROFILE 30X30 to V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30	37	24		20.33	22.37	26.84
A1-22	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	157	124		93.67	103.03	123.64
A1-23	Add V2_002_1000_11_CENTER SUPPORT_00_PROFILE 30X30 in between both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30 and V2_002_1000_09_Z-AXIS MOUNT_00_PROFILE 30X30	156	125		93.67	103.03	123.64
A1-24	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	98	67		55.00	60.50	72.60
A1-25	Add four V2_002_1000_07_BASE Z-AXIS_00_PROFILE 30X30 to V2_002_1000_03_LENGTH BAR_00_PROFILE 30X30	80	64		48.00	52.80	63.36
A1-26	Insert the cap screw size M8 x 35	120	96		72.00	79.20	95.04
A1-27	Insert angle bracket with cap screw size M6 x 12 and flat washer 6M	184	164		116.00	127.60	153.12
A1-28	Add two V2_002_1000_10_CENTER LAMP BAR_00_PROFILE 30X30 between both V2_002_1000_02_HEIGHT BAR_00_PROFILE 30X30	64	40		34.67	38.13	45.76
A1-29	Insert the cap screw size M8 x 35	13	10		7.67	8.43	10.12

No.	Process Description	Time (min)					
		1st(s)	2nd(s)	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
A1-30	Turn the assembly upside down	11	8		6.33	6.97	8.36
A1-31	Add four V2_002_1000_14_LEVELING MOUNT PLATE_00_ALU at each edge	20	13		11.00	12.10	14.52
A1-32	Insert the cap screw size M6 x 25	196	172		122.67	134.93	161.92
A1-33	Insert Wheel Caster and tighten the nut using wrench and aligned stand to ensure it will be stable.	44	36		26.67	29.33	35.20
TOTAL					1579.67	1737.63	2085.16

X-AXIS

NAME: TIME STUDY (X-AXIS ASSEMBLY)		Date of study:					PIC.:
		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
B-1	Attach V2_002_1300_01_X-AXIS MAIN BAR and V2_002_1300_11_X-AXIS LOWER BAR with distance 47.5MM from the end of MAIN BAR.	27	23		16.67	18.33	22.00
B-2	Attach PROFILE LINK PLATE at left on the assembly BAR 9.5mm from end of LOWER BAR. Attach spring washer M6 and tight using Cap Screw M6x16.	255	221		158.67	174.53	209.44
B-3	With the distance between the plates 87.5MM attach another PROFILE LINK PLATE. Put spring washer M6 and tight using Cap Screw M6x16.	265	243		169.33	186.27	223.52
B-4	Repeat the process with another 3 PROFILE LINK PLATE.	1222	1091		771.00	848.10	1017.72
B-5	Rotate the assembly BAR. Attach PROFILE LINK PLATE at the left side with distance 59MM from the end of LOWER BAR. Attach spring washer M6 and tight with Cap Screw M6x16.	420	362		260.67	286.73	344.08
B-6	Repeat the process with another 2 PROFILE LINK PLATE with distance between plate is 190MM.	267	243		170.00	187.00	224.40
B-7	Place RAIL on top of the V2_002_1300_01_X-AXIS MAIN	366	322		229.33	252.27	302.72
B-8	At the left side the distance between RAIL and end of MAIN	276	243		173.00	190.30	228.36

No.	Process Description	Time (min)					
		1st	2nd	3rd	average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
B-9	Put the assembly on the milling machine and use the dial indicator to calibrate the RAIL.	1636	1335		990.33	1089.37	1307.24
B-10	Turn back the entire assembly. place FIXED START MOUNT left and right 88.8mm from the top end of the main axis by using cap screw M5x16.	294	251		181.67	199.83	239.80
B-11	At the left FIXED START MOUNT Attach EF10 on the surface and tighten it by using cap screw M8x35.	189	160		116.33	127.97	153.56
B-12	At the right FIXED START MOUNT Attach EK10 on the surface and tight it by using cap screw M8x35.	113	109		74.00	81.40	97.68
B-13	Attach the BLOCK and SFU BALL NUT with the BALL SCREW.	33	25		19.33	21.27	25.52
B-14	Position the cap screw M4x16 on the SFU BALL NUT and tight it.	180	162		114.00	125.40	150.48
B-15	Insert the BALL SCREW in the EF10 and EK10 slowly and carefully to avoid bearing in the shaft out.	47	33		26.67	29.33	35.20
B-16	Install a grease snipper at the SFU BALL NUT to easily pump in grease.	0	0		0.00	0.00	0.00
B-17	Fasten V2_002_1300_06 ANGLE BLOCK MOUNT on the block USING M4x16.	150	125		91.67	100.83	121.00
B-18	At the right side attach V2_002_1300_02 MOTOR MOUNT 7mm from end MAIN BAR using cap screw M5x12.	75	62		45.67	50.23	60.28

No.	Process Description	Time (min)					
		1st	2nd	3rd	average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
B-19	Insert the circlip in the hole at the RIGID COUPLING.	32	24		18.67	20.53	24.64
B-20	Insert the RIGID COUPLING at the end of the BALL SCREW until it is close and tighten it with a cap screw M2.5x12 using the Allen key.	163	152		105.00	115.50	138.60
B-21	Attach the NEMA STEPPER MOTOR on the V2_002_1300_02 MOTOR MOUNT and tighten it using a cap screw M4x16 with a hexagonal M4 nut.	178	157		111.67	122.83	147.40
B-22	At left install V2_002_1300_08 WIRE DUCT SUPPORT 60	78	69		49.00	53.90	64.68
B-23	Add V2_002_1300_10 CABLE CHAIN PLATE 55mm from the tip on V2_002_1300_01 MAIN BAR and tie using cap screw M5x10.	96	83		59.67	65.63	78.76
B-24	Locate V2_002_1300_09 WIRE TRUCKING on the V2_002	96	83		59.67	65.63	78.76
B-25	Attach the CABLE CHAIN on the V2_002_1300_09 WIRE T	218	206		141.33	155.47	186.56
B-26	At the right front view. Install V2_002_1300_07 LIMIT SWI	95	72		55.67	61.23	73.48
B-27	Attach the LIMIT SWITCH SENSOR on the V2_002_1300_07 LIMIT SWITCH BASE and fasten using the head button screw M3x12.	60	51		37.00	40.70	48.84

No.	Process Description	Time (min)					
		1st	2nd	3rd	average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
B-28	At the top MAIN BAR and bottom LOWER BAR, insert two LINEAR BLOCKS on each rail.	125	109		78.00	85.80	102.96
B-29	Install 1 CORNER BRACKET 3060 at the front V2_002_1300_01 X-AXIS MAIN BAR. 5.1MM from end of MAIN BAR on the left and right side. Put spring washer M6 and tight it by using a cap screw M6x16 .	179	166		115.00	126.50	151.80
B-30	Add two cap screws M6x16 at the top V2_002_1300_01 X-AXIS MAIN BAR at the left and right side.	0	0		0.00	0.00	0.00
B-31	Insert V2_002_1300_12_LINEAR STOPPER beside the RAIL on the left side with 32MM from the end. Tight using Cap Screw M4x25.	171	163		111.33	122.47	146.96
B-32	Insert V2_002_1300_12_LINEAR STOPPER beside the RAIL on the left side with 42MM from the end. Tight using Cap Screw M4x25.	171	163		111.33	122.47	146.96
	TOTAL				4661.67	5127.83	6153.40

Y-AXIS (RIGHT)

NAME:		Date of study:					PIC.:
TIME STUDY (RIGHT Y-AXIS ASSEMBLY)		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
C (b)-1	Insert the CAP SCREWS M4x16 into the LINEAR RAIL and slide in the LINEAR RAIL into V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60.	31	25		18.67	20.53	24.64
C (b)-2	Measure the distance and adjust the position of LINEAR RAIL as per the drawing.	59	36		31.67	34.83	41.80
C (b)-3	Clamp V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and set up the Dial Gauge Indicator on the milling machine.	79	53		44.00	48.40	58.08
C (b)-4	Calibrate the position of the LINEAR RAIL on the V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and tighten the screws.	1335	1064		799.67	879.63	1055.56
C (b)-5	Attach V2_002_1200_01_MOTOR MOUNT_01_ALU on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with M5X10.	364	309		224.33	246.77	296.12
C (b)-6	Attach V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	383	319		234.00	257.40	308.88
C (b)-7	Attach V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	25	19		14.67	16.13	19.36
C (b)-8	Attach UPPER BALL SCREW END MOUNT on the V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) with CAP SCREW M8X35.	101	86		62.33	68.57	82.28
C (b)-9	Attach BLOCK to SFU-1204 with M4X16.	32	29		20.33	22.37	26.84
C (b)-10	Insert BALLSCREW-NUT ASSEMBLY into UPPER BALL SCREW END MOUNT.	109	87		65.33	71.87	86.24
C (b)-11	Adjust the position of Fixed End Mount.	271	236		169.00	185.90	223.08
C (b)-12	Attach LOWER BALL SCREW END MOUNT on V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE) and at the end of BALLSCREW SHAFT with CAP SCREW M8X35.	153	128		93.67	103.03	123.64
C (b)-13	Tighten the screws.	20	14		11.33	12.47	14.96
C (b)-14	Secure the BALLSCREW SHAFT position on the LOWER BALL SCREW END MOUNT with a circlip.	189	153		114.00	125.40	150.48

No.	Process Description	Time (min)					
		1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
C (b)-15	Attach SHAFT COUPLER to MOTOR.	35	27		20.67	22.73	27.28
C (b)-16	Insert the SHAFT COUPLER through V2_002_1200_01_MOTOR MOUNT_01_ALU and attach to BALLSCREW SHAFT.	137	114		83.67	92.03	110.44
C (b)-17	Attach MOTOR on V2_002_1200_01_MOTOR MOUNT_01_ALU with CAP SCREW M4X16.	126	101		75.67	83.23	99.88
C (b)-18	Tighten the screws.	34	23		19.00	20.90	25.08
C (b)-19	Attach V2_002_1200_05_SIDE ANGLE MOUNT_00_ALU on BLOCK CAP SCREW M4X16.	150	136		95.33	104.87	125.84
C (b)-20	Slide in the LINEAR BLOCKS on the LINEAR RAIL.	50	38		29.33	32.27	38.72
C (b)-21	Attach V2_002_1200_04_TOP BLOCK MOUNT_00_ALU on the LINEAR BLOCKS with CAP SCREW M4X10.	215	195		136.67	150.33	180.40
C (b)-22	Adjust the position of Linear Blocks and attach the Top Block Mount with the Side Angle Mount with CAP SCREW M5X20.	157	131		96.00	105.60	126.72
C (b)-23	Attach the V2_002_1200_06_LIMIT SWITCHMOUNT_01_NYLON(BLUE) on the V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREW M5X30.	94	81		58.33	64.17	77.00
C (b)-24	Attach the LIMIT SWITCH SENSOR on the V2_002_1200_06_LIMIT SWITCHMOUNT_01_NYLON(BLUE) with CAP SCREW M3X25.	60	49		36.33	39.97	47.96
TOTAL					2554.00	2809.40	3371.28

Y-AXIS (LEFT)

NAME: TIME STUDY (LEFT Y-AXIS ASSEMBLY)		Date of study:					PIC.:
		Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	Average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
C (a)-1	Insert the CAP SCREWS M4x16 into the LINEAR RAIL and slide in the LINEAR RAIL into V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60.	39	33		24.00	26.40	31.68
C (a)-2	Measure the distance and adjust the position of LINEAR RAIL as per the drawing.	63	57		40.00	44.00	52.80
C (a)-3	Clamp V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and set up the Dial Gauge Indicator on the milling machine.	79	62		47.00	51.70	62.04
C (a)-4	Calibrate the position of the LINEAR RAIL on the V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 and tighten the screws.	1335	1064		799.67	879.63	1055.56
C (a)-5	Attach V2_002_1200_01_MOTOR MOUNT_01_ALU on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with M5X10.	433	419		284.00	312.40	374.88
C (a)-6	Attach V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	422	401		274.33	301.77	362.12
C (a)-7	Attach V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE) on V2_002_1200_07_Y-AXIS MAIN_00_PROFILE 30X60 with CAP SCREWS M5X12.	20	17		12.33	13.57	16.28
C (a)-8	Attach UPPER BALL SCREW END MOUNT on the V2_002_1200_03_FIXED START MOUNT_00_NYLON(BLUE) with CAP SCREW M8X35.	97	82		59.67	65.63	78.76

No.	Process Description	Time (min)					
		1st	2nd	3rd	Average	Normal time (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
C (a)-9	Attach BLOCK to SFU-1204 with M4X16.	39	24		21.00	23.10	27.72
C (a)-10	Insert BALLSCREW-NUT ASSEMBLY into UPPER BALL SCREW END MOUNT.	108	97		68.33	75.17	90.20
C (a)-11	Adjust the position of Fixed End Mount.	280	253		177.67	195.43	234.52
C (a)-12	Attach LOWER BALL SCREW END MOUNT on V2_002_1200_02_FIXED END MOUNT_00_NYLON(BLUE) and at the end of BALLSCREW SHAFT with CAP SCREW M8X35.	160	155		105.00	115.50	138.60
C (a)-13	Tighten the screws.	20	18		12.67	13.93	16.72
C (a)-14	Secure the BALLSCREW SHAFT position on the LOWER BALL SCREW END MOUNT with a circlip.	203	187		130.00	143.00	171.60
C (a)-15	Attach SHAFT COUPLER to MOTOR.	43	36		26.33	28.97	34.76
C (a)-16	Insert the SHAFT COUPLER through V2_002_1200_01_MOTOR MOUNT_01_ALU and attach to BALLSCREW SHAFT.	145	137		94.00	103.40	124.08
C (a)-17	Attach MOTOR on V2_002_1200_01_MOTOR MOUNT_01_ALU with CAP SCREW M4X16.	134	116		83.33	91.67	110.00
C (a)-18	Tighten the screws.	45	31		25.33	27.87	33.44
C (a)-19	Attach V2_002_1200_05_SIDE ANGLE MOUNT_00_ALU on BLOCK CAP SCREW M4X16.	137	122		86.33	94.97	113.96
C (a)-20	Slide in the LINEAR BLOCKS on the LINEAR RAIL.	43	31		24.67	27.13	32.56
C (a)-21	Attach V2_002_1200_04_TOP BLOCK MOUNT_00_ALU on the LINEAR BLOCKS with CAP SCREW M4X10.	191	177		122.67	134.93	161.92
C (a)-23	Adjust the position of Linear Blocks and attach the Top Block Mount with the Side Angle Mount with CAP SCREW M5X20.	132	125		85.67	94.23	113.08
TOTAL					2604.00	2864.40	3437.28

Z-AXIS

NAME: TIME STUDY (Z-AXIS ASSEMBLY)		Date of study: Prepared By: Nur Najihah Nazrin Rasheeqah	Date: 17/7/2023	Checked By:			PIC.: Approved By:
		Time (min)					
No.	Process Description	1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
D-1	calibrate linear rail for the Z-axis	843	743		528.67	581.53	697.84
D-2	attach the V2_002_1400_05_SPACER PLATE_00_ALU to the bottom V2_002_1400_01_MAIN PLATE_00_ALU	32	30		20.67	22.73	27.28
D-3	attach EF10_5 BLOCK to the V2_002_1400_05_SPACER PLATE_00_ALU	25	19		14.67	16.13	19.36
D-4	use the cap screw M8x50	74	56		43.33	47.67	57.2
D-5	insert the Ballscrew through the Block	146	135		93.67	103.03	123.64
D-6	insert the Ball Nut through the Ballscrew and attach it with the Block	354	309		221.00	243.10	291.72
D-7	use the cap screw M4x16	72	59		43.67	48.03	57.64
D-8	insert the ek10 BLOCK to the Ballscrew	208	176		128.00	140.80	168.96
D-9	attach the V2_002_1400_05_SPACER PLATE_00_ALU to the top V2_002_1400_01_MAIN PLATE_00_ALU	245	215		153.33	168.67	202.4
D-10	attach the ek10 BLOCK to the V2_002_1400_05_SPACER PLATE_00_ALU	149	128		92.33	101.57	121.88
D-11	use the cap screw M8x50	37	22		19.67	21.63	25.96
D-12	attach the V2_002_1400_02_TOP PLATE_01_ALU to the V2_002_1400_01_MAIN PLATE_00_ALU	103	91		64.67	71.13	85.36

No.	Process Description	Time (min)					
		1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
D-13	use the cap screw M4x16	33	24		19.00	20.90	25.08
D-14	attach the 4 V2_002_1400_04_BUSH PIPE_00_ALU to the V2_002_1400_02_TOP PLATE_01_ALU	484	467		317.00	348.70	418.44
D-15	use the cap screw M4x16	80	61		47.00	51.70	62.04
D-16	attach the rigid coupling with the STEPPER MOTOR	583	562		381.67	419.83	503.8
D-17	tighten the rigid coupling	207	183		130.00	143.00	171.6
D-18	attach the rigid coupling and the STEPPER MOTOR to the Ballscrew	447	409		285.33	313.87	376.64
D-19	use the cap screw M4x16	44	32		25.33	27.87	33.44
D-20	tighten the rigid coupling	32	21		17.67	19.43	23.32
D-21	attach the sensor inductive proximity to the V2_002_1400_02_TOP PLATE_01_ALU from below	319	301		206.67	227.33	272.8
D-22	attach the limit switch base to the V2_002_1400_02_TOP PLATE_01_ALU from below	328	297		208.33	229.17	275
D-23	use the cap screw M4x16	55	43		32.67	35.93	43.12
D-24	attach the 2 LINEAR RAIL to the V2_002_1400_01_MAIN PLATE_00_ALU	0	0		0.00	0.00	0
D-25	use the cap screw M4x20	0	0		0.00	0.00	0
D-26	insert the 2 LINEAR BLOCK to each side of the LINEAR RAIL	270	255		175.00	192.50	231

No.	Process Description	Time (min)					
		1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
D-27	attach the HG15 STOPPER to the each side of the LINEAR RAIL	207	171		126.00	138.60	166.32
D-28	tighten the HG15 STOPPER	54	39		31.00	34.10	40.92
D-29	insert the dowel pin to the V2_002_1400_09_BLOCK SPACER_01_ALU	77	59		45.33	49.87	59.84
D-30	attach the V2_002_1400_09_BLOCK SPACER_01_ALU to the LINEAR BLOCK on each side	66	53		39.67	43.63	52.36
D-31	use the cap screw M4x30	91	74		55.00	60.50	72.6
D-32	attach the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU to the V2_002_1400_09_BLOCK SPACER_01_ALU by using the dowel pin	139	122		87.00	95.70	114.84
D-33	insert 4 cap screw M4x16 from the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU to the BLOCK	10	8		6.00	6.60	7.92
D-34	insert 6 cap screw M5x25 from the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU to the V2_002_1400_09_BLOCK SPACER_01_ALU	359	341		233.33	256.67	308
D-35	attach the SPINDLE to the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU	60	48		36.00	39.60	47.52
D-36	use the cap screw M6x30	10	8		6.00	6.60	7.92
D-37	attach the speed controller to the coolant main base	138	121		86.33	94.97	113.96
D-38	attach the coolant bolt to the coolant main base	62	59		40.33	44.37	53.24
D-39	attach the coolant main base to the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU	11	9		**6.67**	**7.33**	**8.8**
D-40	use the cap screw M4x30	177	159		**112.00**	**123.20**	**147.84**

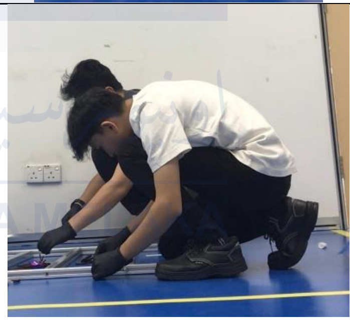
No.	Process Description	Time (min)					
		1st	2nd	3rd	Average	**Normal time** (Normal time = Average time x Rating factor)	**Std Time** (Std time =Normal time x (1 + allowance factor))
D-41	attach the coolant hose connector to the coolant bolt	15	12		**9.00**	**9.90**	**11.88**
D-42	attach the cable chain to the V2_002_1400_06_SPINDLE MOUNT PLATE_01_ALU	90	81		**57.00**	**62.70**	**75.24**
D-43	use button head screw M4x10	43	32		**25.00**	**27.50**	**33**
TOTAL					4271.00	4698.10	5637.72

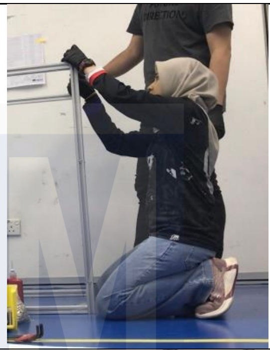
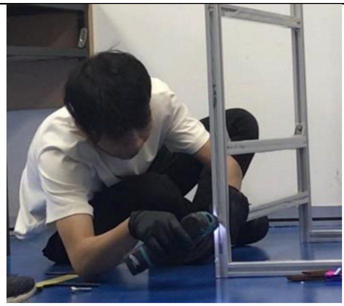
APPENDIX D Rapid Upper Limb Assessment

APPENDIX E Flowchart

APPENDIX D RULA

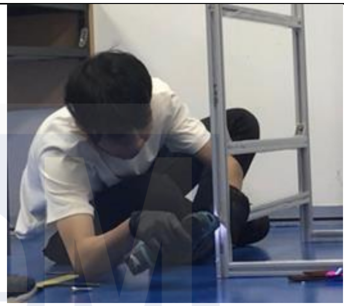
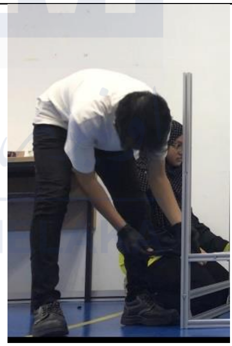
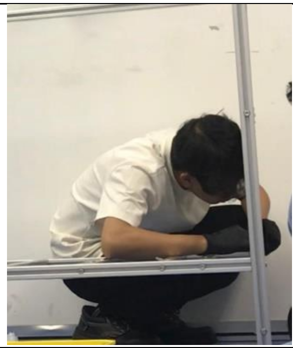
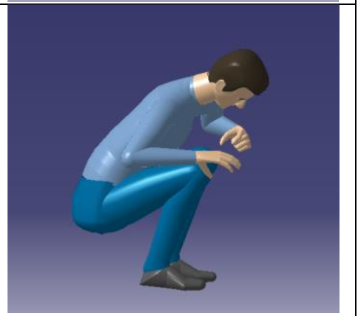
MAIN FRAME

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-1	UPPER ARM	3	7	Investigate and change immediately	134s	69s		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
A1-2	UPPER ARM	3	5	Investigate further and change soon	92s	65s		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-3	UPPER ARM	2	4	Investigate further	197s	125s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

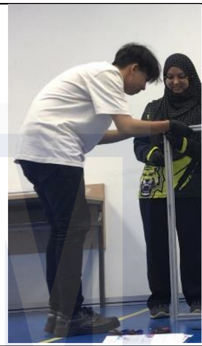
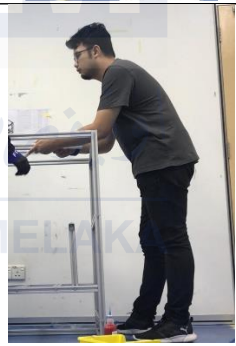
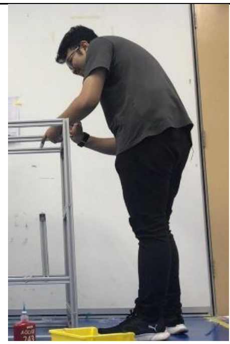
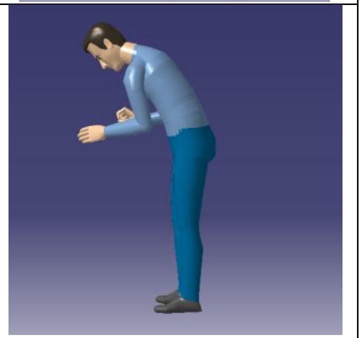
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-4	UPPER ARM	3	4	Investigate further	43s	30s		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	1						
	LEG	1						
	POSTURE B	5						
A1-5	UPPER ARM	2	3	Investigate further	83s	62s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
A1-6	UPPER ARM	4	3	Investigate further	30s	23s		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						

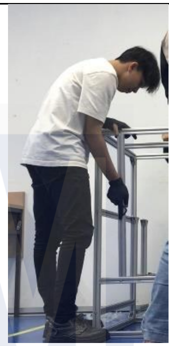
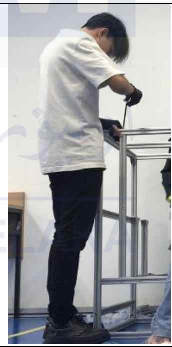
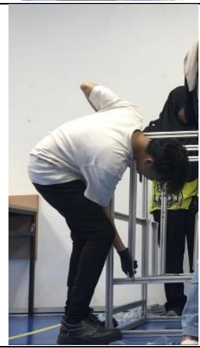
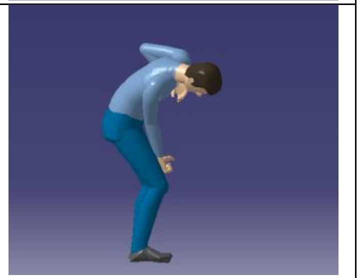
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-7	UPPER ARM	2	4	Investigate further	197s	125s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
A1-8	UPPER ARM	3	4	Investigate further	43s	30s		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	1						
	LEG	1						
	POSTURE B	5						
A1-9	UPPER ARM	2	3	Investigate further	83s	62s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						

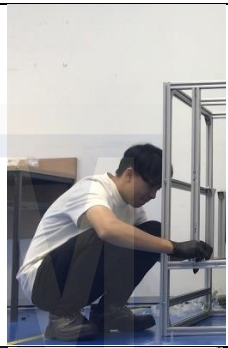
APPENDIX D RULA

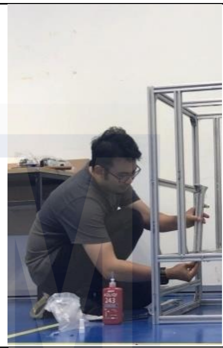
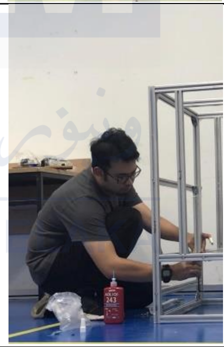
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-10	UPPER ARM	4	3	Investigate further	30s	23s		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-11	UPPER ARM	4	3	Investigate further	92s	68s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-12	UPPER ARM	3	5	Investigate further and change soon	72s	59s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	5						
	LEG	1						
	POSTURE B	6						

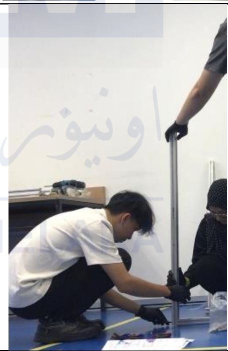
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-13	UPPER ARM	3	3	Investigate further	154s	136s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-14	UPPER ARM	4	3	Investigate further	56s	43s		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-15	UPPER ARM	1	3	Investigate further	46s	42s		
	LOWER ARM	1						
	WRIST	4						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						

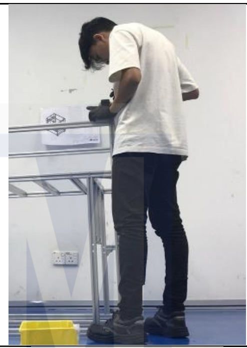
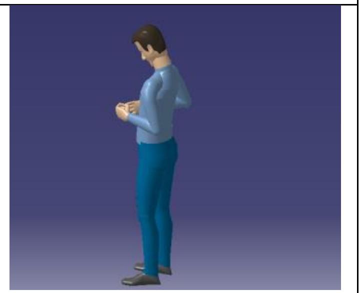
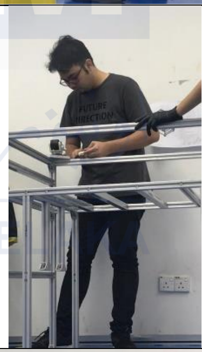
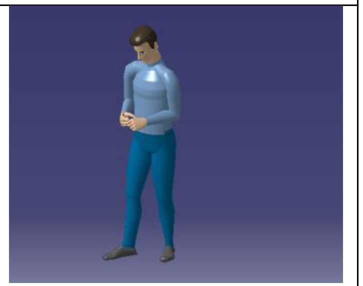
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-16	UPPER ARM	3	7	Investigate and change immediately	51s	43s		
	LOWER ARM	1						
	WRIST	4						
	WRIST TWIST	1						
	POSTURE A	5						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
A1-17	UPPER ARM	3	5	Investigate further and change soon	53s	25s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
A1-18	UPPER ARM	1	6	Investigate further and change soon	25s	18s		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	4						
	TRUNK	5						
	LEG	1						
	POSTURE B	7						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-19	UPPER ARM	2	3	Investigate further	37s	24s		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-20	UPPER ARM	3	3	Investigate further	16s	10s		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
A1-21	UPPER ARM	3	5	Investigate further and change soon	37s	24s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	5						
	LEG	1						
	POSTURE B	6						

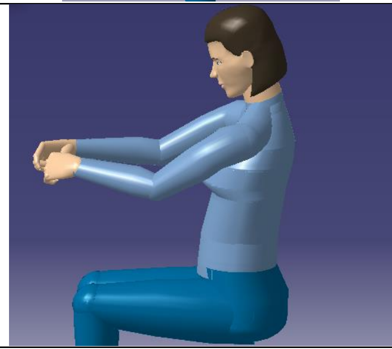
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-22	UPPER ARM	4	3	Investigate further	157s	124s		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-23	UPPER ARM	2	4	Investigate further	156s	125s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
A1-24	UPPER ARM	3	4	Investigate further	98s	67s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-25	UPPER ARM	2	5	Investigate further and change soon	80s	64s		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	5						
	LEG	1						
	POSTURE B	6						
A1-26	UPPER ARM	2	5	Investigate further and change soon	120s	96s		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	5						
	LEG	1						
	POSTURE B	6						
A1-27	UPPER ARM	3	3	Investigate further	184s	164s		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-28	UPPER ARM	5	5	Investigate further and change soon	64s	40s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	6						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-29	UPPER ARM	3	3	Investigate further	13s	10s		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
A1-30	UPPER ARM	2	3	Investigate further	11s	8s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
A1-31	UPPER ARM	2	3	Investigate further	20s	13s		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	1						
	LEG	1						
	POSTURE B	3						
A1-32	UPPER ARM	1	4	Investigate further	196s	172s		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
A1-33	UPPER ARM	1	2	acceptable	44s	36s		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

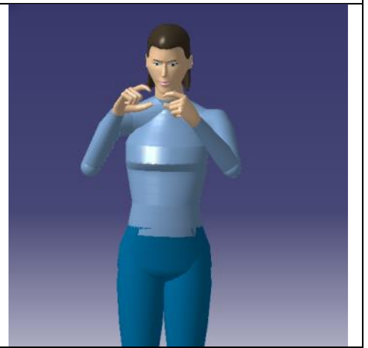
X-AXIS

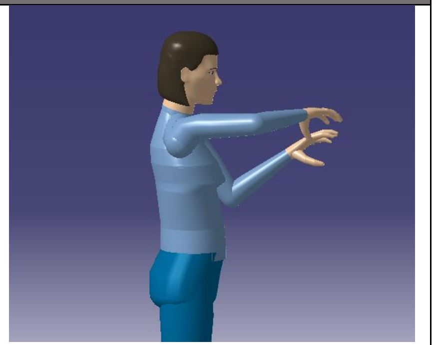
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-1	UPPER ARM	3	3	Investigate further	27s	23		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	2						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-2	UPPER ARM	1	2	Acceptable	255	221		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-3	UPPER ARM	3	3	Investigate further	265	243		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						

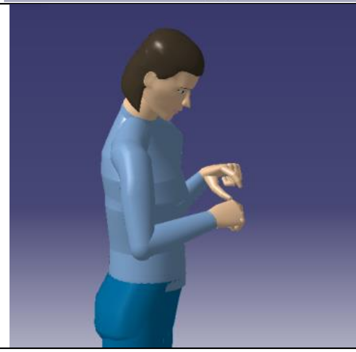
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-4	UPPER ARM	4	6	Investigate further and change soon	1222	1091		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
B-5	UPPER ARM	1	4	Investigate further	420	362		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
B-6	UPPER ARM	2	4	Investigate further	267	243		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

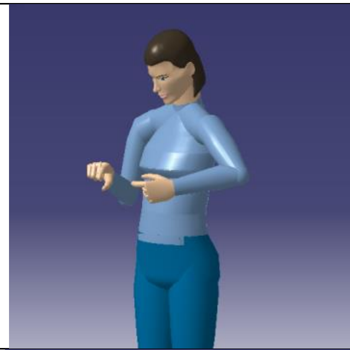
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-7	UPPER ARM	1	6	Investigate further and change soon	366	322		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
B-8	UPPER ARM	2	3	Investigate further	276	243		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-9	UPPER ARM	4	7	Investigate and change immediately	1636	1335		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-10	UPPER ARM	1	2	Acceptable	294	251		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-11	UPPER ARM	1	2	Acceptable	189	160		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-12	UPPER ARM	3	5	Investigate further and change soon	113	109		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-13	UPPER ARM	3	3	Investigate further	33	25		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-14	UPPER ARM	3	3	Investigate further	180	162		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE Av	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-15	UPPER ARM	3	5	Investigate further and change soon	47	33		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

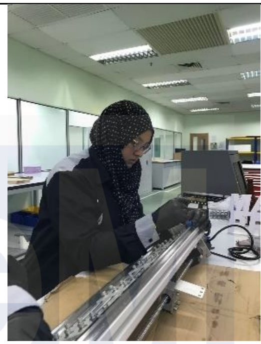
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-16	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
B-17	UPPER ARM	4	3	Investigate further	150	125		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
B-18	UPPER ARM	3	3	Investigate further	75	62		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-19	UPPER ARM	3	3	Investigate further	32	24		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
B-20	UPPER ARM	3	5	Investigate further and change soon	163	152		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	3						
	LEG	1						
	POSTURE B	6						
B-21	UPPER ARM	2	4	Investigate further	178	157		
	LOWER ARM	3						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

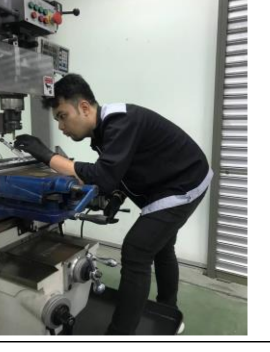
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-22	UPPER ARM	1	3	Investigate further	78	69		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-23	UPPER ARM	2	4	Investigate further	96	83		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
B-24	UPPER ARM	1	2	acceptable	96	83		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						

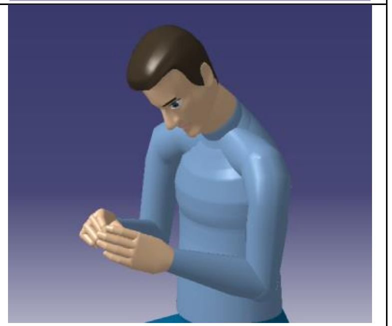
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-25	UPPER ARM	2	3	Investigate further	218	206		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-26	UPPER ARM	2	4	Investigate further	95	72		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
B-27	UPPER ARM	3	4	Investigate further	60	51		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

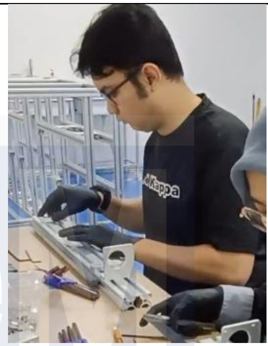
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-28	UPPER ARM	1	3	Investigate further	125	109		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	2						
	POSTURE A	3						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
B-29	UPPER ARM	1	2	acceptable	179	166		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-30	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							

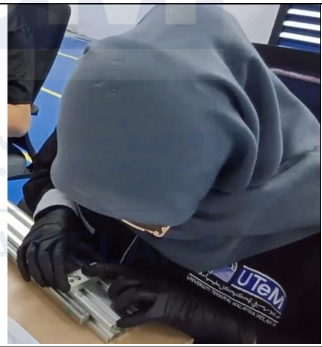
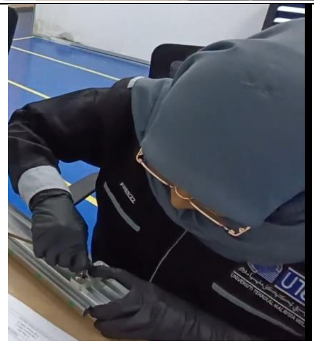
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
B-31	UPPER ARM	2	3	Investigate further	171	163		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
B-32	UPPER ARM	2	3	Investigate further	171	163		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

Y-AXIS ASSEMBLY LEFT

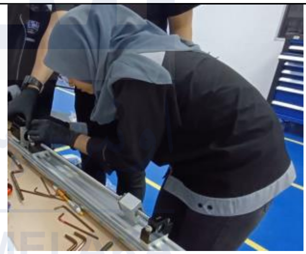
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-1	UPPER ARM	2	3	Investigate further	39	33		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (a)-2	UPPER ARM	1	3	Investigate further	63	57		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (a)-3	UPPER ARM	1	6	Investigate further and change soon	79	62		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	SCORE B	6						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-4	UPPER ARM	1	4	Investigate further	1335	1064		
	LOWER ARM	1						
	WRIST	4						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
C (a)-5	UPPER ARM	2	3	Investigate further	433	419		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (a)-6	UPPER ARM	2	3	Investigate further	422	401		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

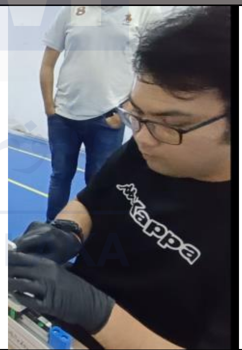
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-7	UPPER ARM	2	3	Investigate further	20	17		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (a)-8	UPPER ARM	2	4	Investigate further	97	82		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	2						
	LEG	1						
	POSTURE B	5						
C (a)-9	UPPER ARM	2	3	Investigate further	39	24		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-10	UPPER ARM	3	3	Investigate further	108	97		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (a)-11	UPPER ARM	1	3	Investigate further	280	253		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (a)-12	UPPER ARM	2	4	Investigate further	160	155		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

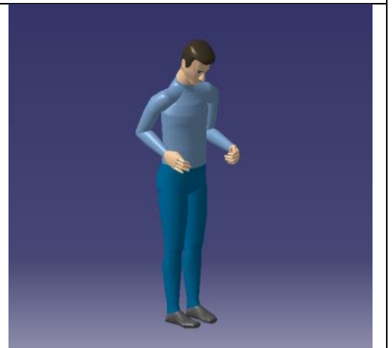
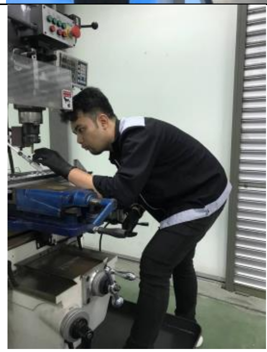
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-13	UPPER ARM	2	4	Investigate further	20	18		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
C (a)-14	UPPER ARM	2	4	Investigate further	203	187		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
C (a)-15	UPPER ARM	1	3	Investigate further	43	36		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						

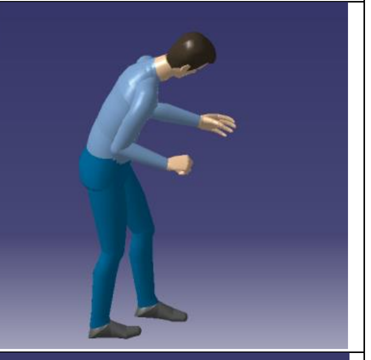
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-16	UPPER ARM	1	3	Investigate further	145	137		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (a)-17	UPPER ARM	3	6	Investigate further and change soon	134	116		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	4						
	LEG	1						
	POSTURE B	7						
C (a)-18	UPPER ARM	1	4	Investigate further	45	31		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

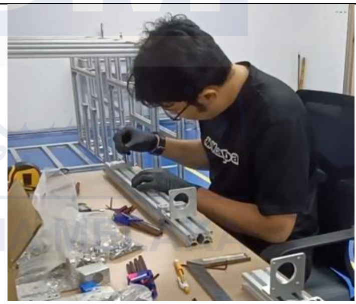
TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-19	UPPER ARM	3	3	Investigate further	137	122		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (a)-20	UPPER ARM	1	4	Investigate further	43	31		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
C (a)-21	UPPER ARM	3	3	Investigate further	191	177		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

TASK NO.	RULA SCORE				TIME (s)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
C (a)-22	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
C (a)-23	UPPER ARM	2	3	Investigate further	132	125		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (a)-24	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							

Y-AXIS ASSEMBLY RIGHT

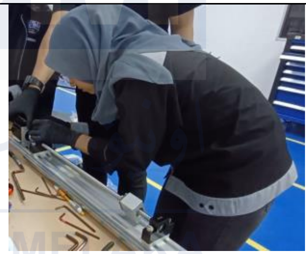
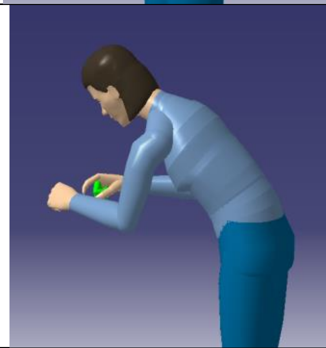
TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-1	UPPER ARM	2	3	Investigate further	31	25		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (b)-2	UPPER ARM	1	3	Investigate further	59	36		
	LOWER ARM	1						
	WRIST	2						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	2						
	TRUNK	2						
	LEG	1						
	SCORE B	2						
C (b)-3	UPPER ARM	1	6	Investigate further and change soon	79	53		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	SCORE B	6						

TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-4	UPPER ARM	1	4	Investigate further	1335	1064		
	LOWER ARM	1						
	WRIST	4						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
C (b)-5	UPPER ARM	2	3	Investigate further	364	309		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (b)-6	UPPER ARM	2	3	Investigate further	383	319		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

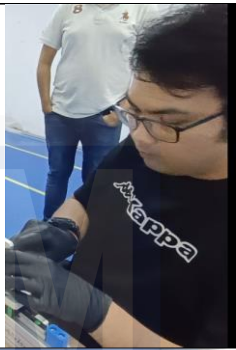
TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-7	UPPER ARM	2	3	Investigate further	25	19		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (b)-8	UPPER ARM	2	4	Investigate further	101	86		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	2						
	LEG	1						
	POSTURE B	5						
C (b)-9	UPPER ARM	2	3	Investigate further	32	29		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-10	UPPER ARM	3	3	Investigate further	109	87		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (b)-11	UPPER ARM	1	3	Investigate further	271	236		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (b)-12	UPPER ARM	2	4	Investigate further	153	128		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

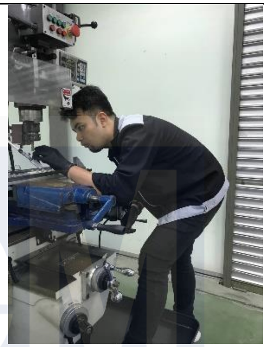
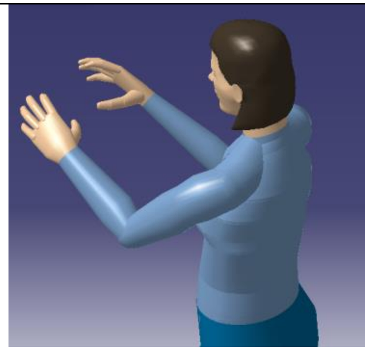
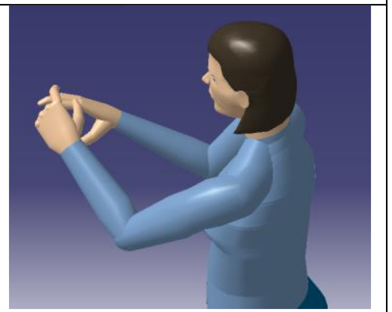
TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-13	UPPER ARM	2	4	Investigate further	20	14		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
C (b)-14	UPPER ARM	2	4	Investigate further	189	153		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
C (b)-15	UPPER ARM	1	3	Investigate further	35	27		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						

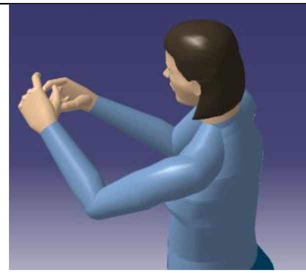
TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-16	UPPER ARM	1	3	Investigate further	137	114		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	1						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (b)-17	UPPER ARM	3	6	Investigate further and change soon	126	101		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	4						
	TRUNK	4						
	LEG	1						
	POSTURE B	7						
C (b)-18	UPPER ARM	1	4	Investigate further	34	23		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	2						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-19	UPPER ARM	3	3	Investigate further	150	136		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	3						
	TRUNK	2						
	LEG	1						
	POSTURE B	3						
C (b)-20	UPPER ARM	1	4	Investigate further	50	38		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	2						
	NECK	2						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
C (b)-21	UPPER ARM	3	3	Investigate further	215	195		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

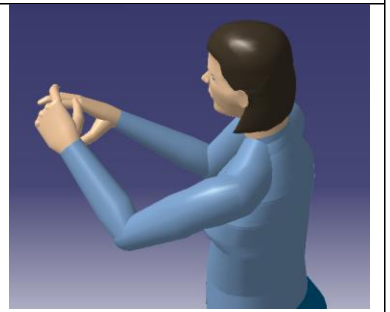
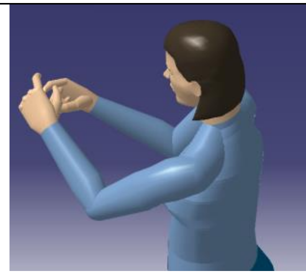
TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
C (b)-22	UPPER ARM	2	3	Investigate further	157	131		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (b)-23	UPPER ARM	2	3	Investigate further	94	81		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
C (b)-24	UPPER ARM	3	3	Investigate further	60	49		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

Z-AXIS ASSEMBLY

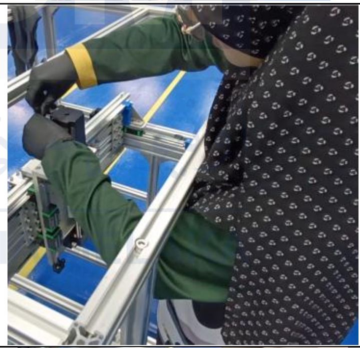
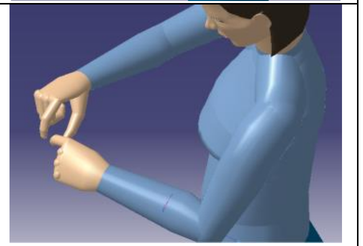
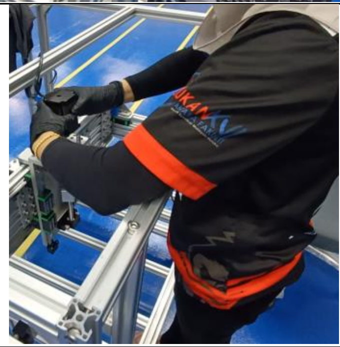
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-1	UPPER ARM	1	6	Investigate further and change soon	843	743		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	2						
	NECK	4						
	TRUNK	3						
	LEG	1						
	SCORE B	6						
D-2	UPPER ARM	3	3	Investigate further	32	30		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	SCORE B	1						
D-3	UPPER ARM	3	3	Investigate further	25	19		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	SCORE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	SCORE B	1						

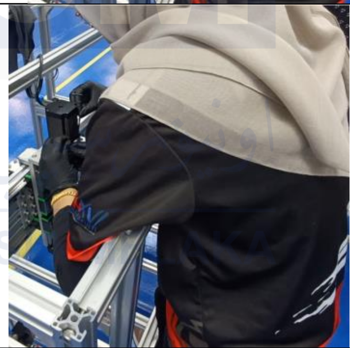
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-4	UPPER ARM	3	3	Investigate further	74	56		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
D-5	UPPER ARM				146	135		
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
D-6	UPPER ARM				354	309		
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-7	UPPER ARM				72	59		
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
D-8	UPPER ARM				208	176		
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
D-9	UPPER ARM	4	3	Investigate further	245	215		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

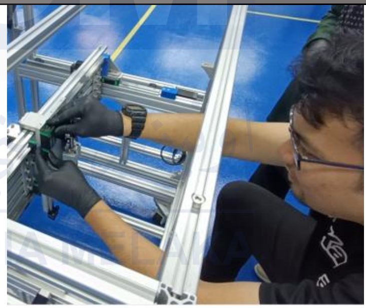
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-10	UPPER ARM	3	3	Investigate further	149	128		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
D-11	UPPER ARM	3	3	Investigate further	37	22		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
D-12	UPPER ARM	4	3	Investigate further	103	91		
	LOWER ARM	2						
	WRIST	2						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

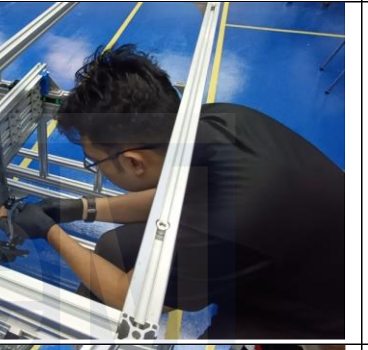
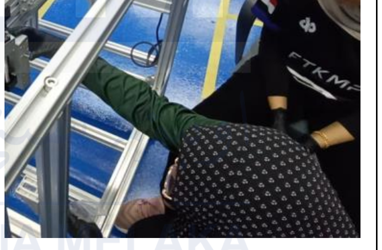
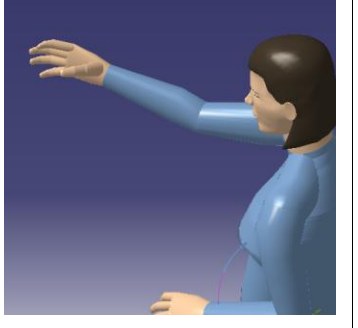
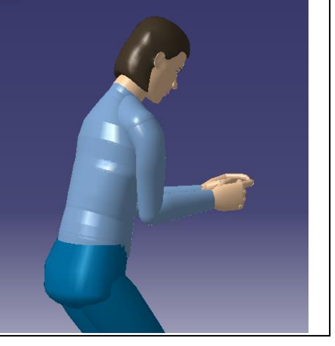
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-13	UPPER ARM	3	4	Investigate further	33	24		
	LOWER ARM	1						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
D-14	UPPER ARM	3	4	Investigate further	484	467		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	3						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						
D-15	UPPER ARM	3	4	Investigate further	80	61		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	3						
	TRUNK	3						
	LEG	1						
	POSTURE B	4						

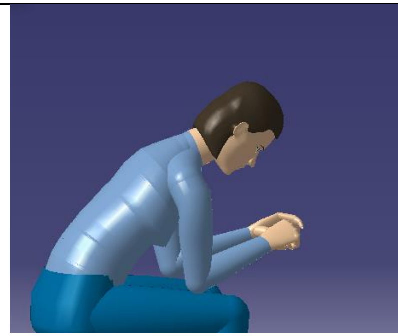
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-16	UPPER ARM	2	3	Investigate further	583	562		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
D-17	UPPER ARM	3	3	Investigate further	207	183		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
D-18	UPPER ARM	2	3	Investigate further	447	409		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

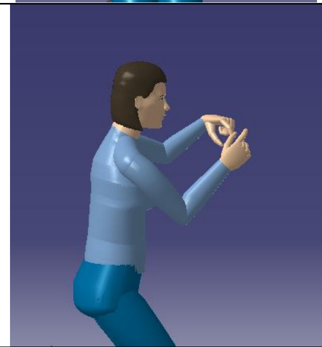
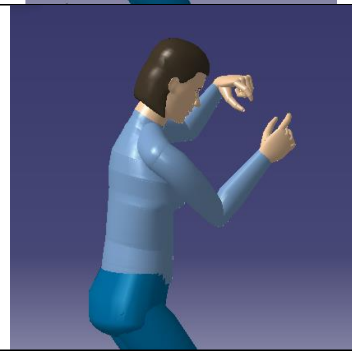
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-19	UPPER ARM	1	3	Investigate further	44	32		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
D-20	UPPER ARM	1	3	Investigate further	32	21		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
D-21	UPPER ARM	3	6	Investigate further and change soon	319	301		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

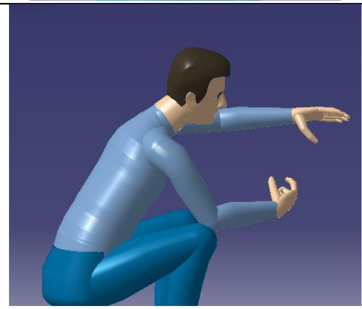
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-22	UPPER ARM	3	6	Investigate further and change soon	328	297		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
D-23	UPPER ARM	3	6	Investigate further and change soon	55	43		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	2						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						
D-24	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							

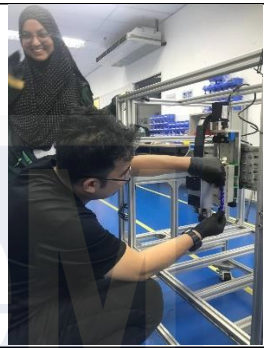
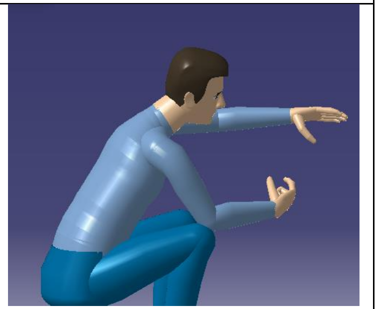
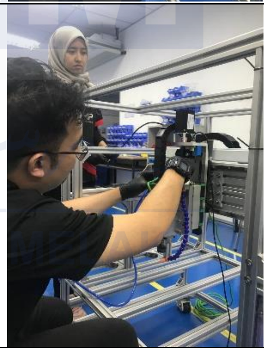
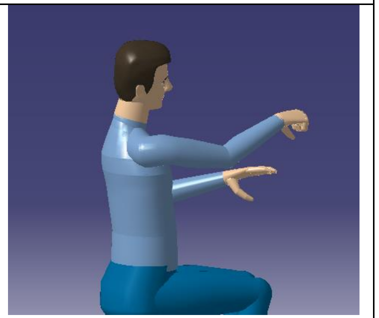
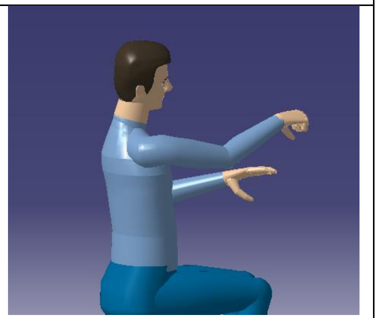
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-25	UPPER ARM							
	LOWER ARM							
	WRIST							
	WRIST TWIST							
	POSTURE A							
	NECK							
	TRUNK							
	LEG							
	POSTURE B							
D-26	UPPER ARM	3	3	Investigate further	270	255		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
D-27	UPPER ARM	3	3	Investigate further	207	171		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-28	UPPER ARM	3	3	Investigate further	54	39		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
D-29	UPPER ARM	3	3	Investigate further	77	59		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
D-30	UPPER ARM	2	4	Investigate further	66	53		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	4						
	LEG	1						
	POSTURE B	5						

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-31	UPPER ARM	3	3	Investigate further	91	74		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	2						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						
D-32	UPPER ARM	2	3	Investigate further	139	122		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						
D-33	UPPER ARM	3	3	Investigate further	10	8		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	3						
	LEG	1						
	POSTURE B	3						

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-34	UPPER ARM	3	5	Investigate further and change soon	359	341		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	2						
	LEG	1						
	POSTURE B	5						
D-35	UPPER ARM	3	5	Investigate further and change soon	60	48		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	2						
	LEG	1						
	POSTURE B	5						
D-36	UPPER ARM	3	3	Investigate further	10	8		
	LOWER ARM	1						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	1						
	TRUNK	2						
	LEG	1						
	POSTURE B	2						

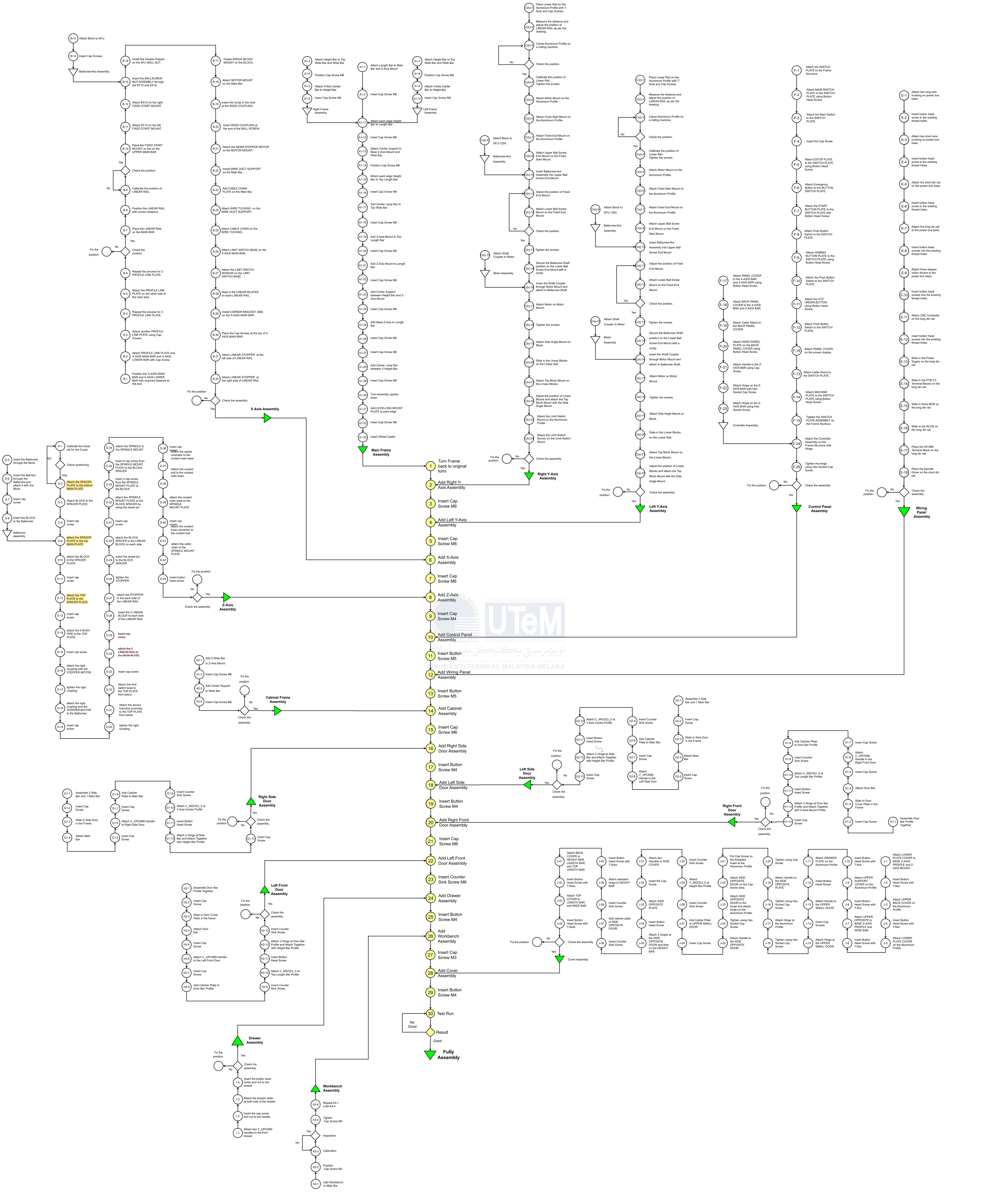
TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-37	UPPER ARM	3	3	Investigate further	138	121		
	LOWER ARM	2						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	3						
	NECK	1						
	TRUNK	1						
	LEG	1						
	POSTURE B	1						
D-38	UPPER ARM	3	5	Investigate further and change soon	62	59		
	LOWER ARM	3						
	WRIST	1						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	4						
	TRUNK	2						
	LEG	1						
	POSTURE B	5						
D-39	UPPER ARM	3	6	Investigate further and change soon	11	9		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	5						
	TRUNK	3						
	LEG	1						
	POSTURE B	7						

TASK NO.	RULA SCORE				TIME (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT	1st	2nd		
D-40	UPPER ARM	3	6	Investigate further and change soon	177	159		
	LOWER ARM	2						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	5						
	TRUNK	3						
	LEG	1						
	POSTURE B	7						
D-41	UPPER ARM	3	3	Investigate further	15	12		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						
D-42	UPPER ARM	3	3	Investigate further	90	81		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						

TASK NO.	RULA SCORE				TIME TAKEN (SEC)		ACTUAL PICTURE	SIMULATION
	PLACE	SCORE	TOTAL	IMPROVEMENT				
D-43	UPPER ARM	3	3	Investigate further	43	32		
	LOWER ARM	3						
	WRIST	3						
	WRIST TWIST	1						
	POSTURE A	4						
	NECK	2						
	TRUNK	1						
	LEG	1						
	POSTURE B	2						

KESIDANG PROCESS FLOW DIAGRAM

APPENDIX E FLOWCHART



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: DESIGN MANUFACTURING INTERFACE: FEASIBILITY STUDY ON ASSEMBLY PROCESS TIME ESTIMATION (TIME STUDY) AND ERGONOMIC OF KESIDANG CNC 3D ROUTER

SESI PENGAJIAN: **2023/24 Semester 1**

Saya **MUHAMMAD ANIQ NAJMI BIN AZIZI**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
√	TIDAK TERHAD	

Disahkan oleh:

MUHAMMAD ANIQ NAJMI

Dr Hambali Bin Boejang

Alamat Tetap:

Hadapan Klinik Desa Kg Delima,

16250, Wakaf Bharu,

Kelantan

Cop Rasmi:

Tarikh: 10/01/2024

Tarikh: 07/02/2024

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.