INTEGRATION OF SIMULATION FOR ERGONOMICS ASSESSMENT IN OPERATION CONTROL CENTRE (RAILWAY INDUSTRIES)

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INTEGRATION OF SIMULATION FOR ERGONOMICS ASSESSMENT IN OPERATION CONTROL CENTRE (RAILWAY INDUSTRIES)

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ABSTRACT

As human-machine interface grow more immersive and graphically-oriented, ergonomics assessment can be simulated with the integration of different design software to replicate real life operation. This can optimize the Operation Control Centre design thus reduce the construction cost and ensure the high comfort level during operation. This study will focus on the translation of the CAD/Revit model into simulation software, either directly or through the intermediate stage of rendering package. Complete CAD/Revit model can be used to generate simulation model by straight forward translation of the whole model or with the algorithms for optimization. Hence this simulation-based system can be used to verify the performance of ergonomics factor related to the operation processes. On top of that, this research also has generate the initial data of Rapid Upper Limb Analysis (RULA). Sample result of posture 3 which involving large movement cause higher RULA result which show the ergonomics assessment need to be further optimize.

ABSTRAK

Kemajuan integrasi antara manusia dan teknologi atau mesin menjadi lebih menonjol dengan berkembangnya teknologi berorientasikan grafik. Ini menjadikan penilaian ergonomik perkara yang menjadi pilihan dalam menyelesaikan masalah sistem operasi antara manusia dan mesin. Kemajuan ini boleh disimulasikan dengan integrasi perisian reka bentuk yang berbeza untuk mengadaptasikan operasi kehidupan sebenar. Ini dapat mengoptimumkan reka bentuk Pusat Kawalan Operasi, dengan in dapat mengurangkan bajet pembinaan dan memastikan tahap keselesaan yang tinggi semasa operasi. Kajian ini menumpukan kepada penterjemahan model CAD / Revit ke dalam perisian simulasi, sama ada secara langsung atau melalui peringkat perantaraan. Kelengkapan model CAD / Revit boleh digunakan untuk menjana model simulasi dengan terjemahan lurus ke hadapan seluruh model atau dengan algoritma untuk pengoptimuman. Oleh itu, sistem berasaskan simulasi ini boleh digunakan untuk mengesahkan prestasi faktor ergonomik yang berkaitan dengan proses operasi. Selain daripada itu, kajian ini telah menunjukkan penilaian awal berdasarkan keputusan Rapid Upper Limb Analysis (RULA). Seperti contoh, pergerakan simulasi ke-3 yang melibatkan pergerakan yang besar menyebabkan keputusan (RULA) yang lebih tinggi, ini menunjukkan penilaian ergonomik perlu diperbaiki untuk mencapai tahap optimum.

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LIST OF ABBREVIATIONS

OCC	Operation Control Center
HMI	Human machine interface
CAD	Computer aided design
3D	Three dimensional
DHM	Digital human modelling
RULA	Rapid Upper Limb Analysis

CHAPTER 1

INTRODUCTION

1.1 Research Background

In the advancement of and the rise of major industries in the world, operation control has played significant roles in human machine interface (HMI) and software interface in various industries which has been integrated into a dedicated room that called an Operation control center (OCC). The control center application concept at those industries are to integrate the technologies available in developing the monitoring and control operations. The major industries that adapt this function are power generation, aviation and telecommunication. Other industries such public transport operation (Railway), manufacturing and logistics area also start to embrace the function. This control room implementations have mostly resulting improve operational performance, reduction of manpower usage and thus increase business profit. These advantages have led the control room concepts to be growing rapidly and it has driven the success in various industries sectors.

The scope of control center concept and design mostly developed is to centralize the information between systems available with the operation interface. This will provide the whole picture of the activities and been illustrated synchronously. Those implementations have shifted the view of control center to be the center brain of the operation and studies have been more concentrated in order to simplify industrial operations and create more effective results.

Recent design factor of control center are more focus on establishing the improvement human-machine and the technology interaction. Through the hierarchical task analysis which has been define early stage and the required core software technological available in control center application. Study are conducted to improve the performance interaction by enhancing human's capabilities in operating technologies thus ensure the control operation more effective and efficient. Various result have shown the operator works becoming more seamless but large dependent on machines.

This technologies integration dependent has resulting drawbacks to the human who are the frequent users of the system. Recent study show that the long working hours in control centers can cause many physical and psychological impacts to the operators as the main result. One of major contribution is unsuitable working postures that occur during work processes which cause pain and musculoskeletal disorders (MSD) in employees. MSD negatively affect the performance of employee and the quality of operation. Examination and evaluation of working postures reveal, the MSD problem has been continuously subjected to employee.

Repetition of physical movements such as stretching, twisting and bending resulting pain or strain in muscles and nerve. This movement also creating some bad effect to soft tissues during work and long hour exposure increase the risk factors for getting MSD. With no preventive measures by determining the risks this may becoming the origin thus suitable working postures are important for the employee's health.

A risk can be created by setting up the improper work environment and selecting unsuitable equipment arrangement. In order to reduce the work-related musculoskeletal disorders complaints, it is necessary to improve the incorrect posture on operation control center. Ergonomically correct and suitable technical solution ensure stress reduction in active muscles such as pain in the neck, waist and lower back.

For these reasons, simulation of ergonomics was frequently used to predict ergonomic problems before the physical existence of the product and process. Three Dimensional 3D visualization of their models with sufficient realism to be used among other activities for design review, management systems, and training. To achieve these objectives, 3D visualization systems are being developed. The efficiency is related to its immersion and interactivity capabilities with the technologies and software, which requires a real-time system response to the user or model requests. 3D model integration provides the capabilities to visualize the possible solution for ergonomics. In the operating process, a series of human related issues are simulated and studied to demonstrate the benefits of a virtual operating approach to product design, workplace design, and time.

Using a software tool, the accuracy of ergonomics analysis depends strongly on the accuracy of simulated postures. Manual manipulation by software users of digital human postures can introduce development in real time. A posture prediction method based on collection data on manual assembly method concerned with assembly features and human diversity will not only provide effective control of digital human in the virtual environment that closely simulates the actual assembly task, but will also provide a clearer understanding of human performance during the operation.

This research is conducted to gather supporting information from simulation knowledge of Railway OCC designers and users / operators along with explicit knowledge of researchers and scholars in the related field of development of OCC. This is to raise awareness of the importance of ergonomics and usability from different perspectives to be implemented in control center designs and improvements that suitable for long hour activity. These disclosures will help to investigate and reduce the MSD affect and invest in improving control centers to achieve operational performance by enhancing their operator’s support systems. It can be considered as a guideline for conducting control center environment operations.

Finally, a model for designing and improving control centers will be suggested to support research discussions and recommendations. The model will be built from the system designer CATIA V5. In this paper, for process validation and human posture validation, ergonomics simulation is used to perform ergonomics analysis. The main focus of the simulation of ergonomics is to use biomechanical models and data to assess the gesture of variation and the critical gesture

1.2 Problem Statement

Long hour of operation and critical control in operation control center always can cause many physical and psychological impacts to the operators in long term. The negative ergonomics and improper equipment or workstation arrangement will result in various health issues. This also reflected in the construction arrangement and cost which will impacted as the operation control center equipment or workstation arrangement might increase the space of console table which does not comply with operation team requirement. Design optimization and ergonomics simulation will increase the feasibility of the design by having a good computed based simulation. Human posture and prediction in manual assembly process become the focus area.

1.3 Objectives

The objectives of this research report are as follows:

1. To investigate the generic approach of CAD/Revit models integrate into other simulation software system.

2. To simulate ergonomics assessment on a working operation control center based on manual layout.

3. To identify the parameters and acceptable conditions of operation control center.

1.4 Structure of the report

This report consists of five chapters starting with Chapter One as the introduction of the project and ended with Chapter Five as the conclusion of the project. The structure of the report are categorized in chapter by chapter.

Chapter One is the introduction that gives brief explanation about the research project. It consists of background of the research, problem statement, objectives and structure of the report.

Chapter Two presents a literature review which covers background discussion of the human ergonomics principle in the design of work system and briefly cover the ISO that been use for ergonomics design. A part from that, the literature review also cover the implementation of CAD/Revit and ergonomics simulation based the operation control center model that has been develop.

Chapter Three describes the methodology of the CAD/Revit model preparation of operation control center and the human simulation ergonomics model been develop and subjected to several parameter based on existing operation control center model.

Chapter Four presenting the results from this research with the supporting information from various sources. Based on the simulated human model, data has been collected and information from different parameter that are related to particular control centers' operations.

Chapter Five In the conclusion part, the final discussion from results and analysis of the research will be summarized. Achievements in the research are finalized in this part, which can be used as guideline for design and improvement criteria.

CHAPTER 2

LITERATURE REVIEW

2.1 Ergonomics of human

In the era of globalization, ergonomics of human at their work place has become one of the major consideration in workplace design. Ergonomics at workplace also has intensively studied in past decade as more HMI been use. There are several regulation that has been set as standard such as applying ergonomic knowledge in the light of practical experience in the design of a work system is intended to satisfy human requirements, (*International Standard Iso structures*, 2015).

Aside from the suggestion of (*EAAP32, Cascai (2016*), it is not possible to adjust the physical characteristics of humans to support the work, so it is the characteristics of the work that need to be developed to support humans. The main reasons for making use of human tools are to simplify their work, improve their work performance, and reduce their working time due to each personal has their own work limitations.

(Murrell, Repository, 2009) stated that human beings have limitations and constrain that will affect their ability to work. This constrain that can be divided into two dimensions, first is anatomical limitations and followed with mental limitations. Furthermore, as discussed by (Krogh, 2005) knowledge is claimed to be another type of human limitation. The first limitation is the limitations of anatomy or physical limitations also has been emphasize by (Kroemer, Kroemer, & Kroemer-Elbert, 2010). Body size, sight and vision, muscle and movement, hearing and metabolism rate are examples of human anatomical limitations.

Those limitation can be more disturb with presence of noise, surrounding temperature, air flow, air pressure, color, humidity. All those factors related to these limitations are the criteria that need to be consider in using control system in monitoring and controlling design, apart from major human limitations that relate to control center activity. (Murrell, Repository, 2009)

Next limitation are mental and mind limitations or psychological limitations. Each individual have perceptions in their lives in all kinds of activities in the personal sense. These perceptions have influential effects on the attitude of humans, which have direct effects on their working conditions and performance.(Karwowski, 2012) Stress is one of the psychological perception, social interaction, and pressure are some examples of mental limitations. (Moore & Barnard, 2012)

All these limitations are each person's individual restrictions. However, studies showed, some common restrictions or there are minor differences among individual, for example, muscle system limitation movement, work stress / pressure, and work environment temperature / humidity. The design of the work system should focus on reducing these difficulties which could affect the ability of humans to work.

Beside the two major limitation, various concerns about the validity and applicability of research into human factors have been recognized. The difficulty of generalizing cognitive psychology research findings based on real-world situations due to optimal experimental conditions (Szalma, 2014). This can be seen in which cognition is evaluated and studies are conducted in similar environments. The recorded and analyze data that focus on the performance of practical work, result showed that psychological, the individual characteristics, and the variable emotional states often provide minor effects on the behavior and performance of the technical and the physical environment of workplace.

(Ed & Goebel, 2013) has highlighted the challenge of collecting the right data in the light of numerous possible human factors measures and the difficulty of reporting the respective findings to experts on non-human factors. Nevertheless, although a complete understanding of the applicability of human factors to task performance is lacking from the perspective of safety engineering, the paramount importance of human factors science and its potential to improve system security and performance has been recognized (Kogi, 2012).

Finally, as one of the factors, human anthropometry was also studied. Anthropometry is study of the human body's measurements and proportions. It determines a person's physical geometry, mass properties, and strength capacity. (Fa, Kamat, Shamsuddin, Darina, & Daruis, 2018). This study uses the classification and comparison of anthropology.

Anthropometric data informs a range of companies that rely on knowledge of measurement distribution across human populations. As for sample (Moore & Barnard, 2012) showed, a known range of human measurements can help guide product design to fit most people in the analysis of human factors. The quantitative comparison of anthropometric data with measurements of patients for planning and evaluation of plastic and reconstructive surgery before and after surgery (Brolin, 2012).

2.2 Operation control center

Today's technology advancement and access to enhanced job interfaces of the one hand activity reduces working hours in hazardous industrial environments. On the other hand, signifies the human role in directing and managing such complex systems.(Iwase & Saijou, 2015). Previous reports and documents suggest that inappropriate allocation of certain tasks to the human side could lead to near-misses, accidents, or even disasters in employment (Taylor et al., 2012).

Control rooms, representing significant levels of human-machine interactions that can be considered as socio-technical systems.(Designing & Room, n.d.). The role of the operator in control centers occurs in a timely manner, which is one of the most important determinants of whether or not an expected action will succeed. In such contexts, the required tasks are defined as either receiving information through different display types or monitoring and adjusting the process flow of operation through designated controls (Kontogiannis & Hollnagel, 1998).

The existing interfaces and the complex nature of the work with predefine processes that has been prepared will affect the dynamic requirements of the cognition of the operator. Studies showed making the control tasks unnecessarily difficult (Shirom, Toker, Alkaly, Jacobson, & Balicer, 2011) creating a large side effect in term of the availability of the operator to fully control the HMI. This can be counter back by developing efficient and consistent applications and functions of control center technologies which has tremendous relationships with knowledge of ergonomics (Pikaar, Thomassen, Degeling, & Van Andel, 1990).

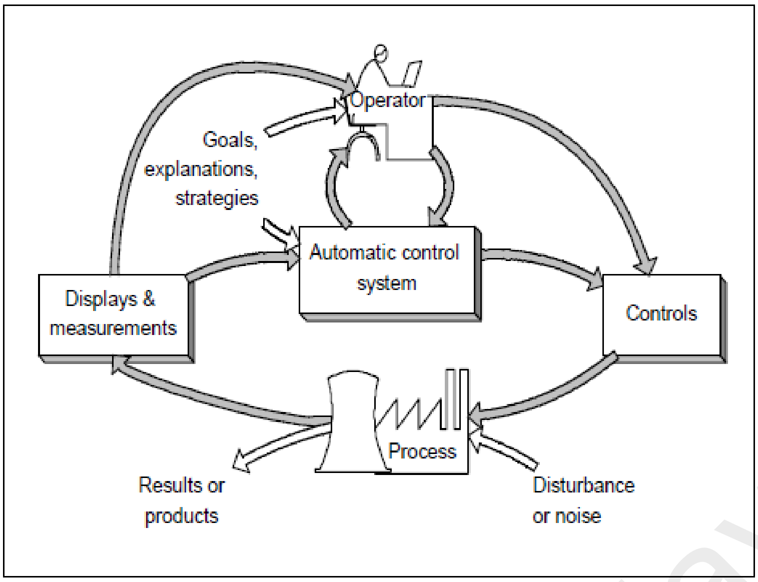


Figure 1: Basic function and interface of control center

To support the ease of use and usability of the advancement of technology interface with the operator. This function are aim to reduce the operators loads in physical, psychological and sociological problems. Latest tools are needed in advanced control rooms as the entire control room concept has develop and combination of technological developments (e.g. computerization, process status overviews, and workstations) have implications both for the cognitive nature of work and for the physical nature of operator activities (Kontogiannis & Hollnagel, 1998).

More specifically, the predominance of advanced information technology means operators become more dependent on specialized tools for retrieving, controlling and communicating information. How operators shape their tools and the tool characteristics that affect individual strategies are critical to our understanding of human computer interaction. In addition, technology uses nowadays provide virtual systems that reduce people's chances of interacting with realities, making the work in the control room more stagnant and require spending long hours of monitoring time.

Major ergonomic considerations for the workplace are work station position, which includes reach and grasp distance, work zone layout, line of sight, and work height, in order to overcome these critical issues. Working position is also important, together with seated and standing work, and finally furniture and equipment design. With the advent of technological improvements, there has been a move to merge control of different processes into a single unit known as the control center through computerization (Seebaran, Lewis, & King, 2015).

The dimension is ergonomics of operation control center majorly involves the physiological factors in the working operations that directly affect the result of the work. Besides information ergonomics, which also includes operations that require tools to support the work of humans. It refers to activities that require the transfer of information between humans and tools to produce a result, and mostly relates to the psychological aspect. With the involvement of control centers as the following example, the difference between the two types of ergonomics can be clarified. When an operator operates the control system, biomechanical ergonomics relate the monitoring activities and operate the control panel, focusing only on the interaction between man and tools (Hugo, Kovesdi, & Joe, 2018).

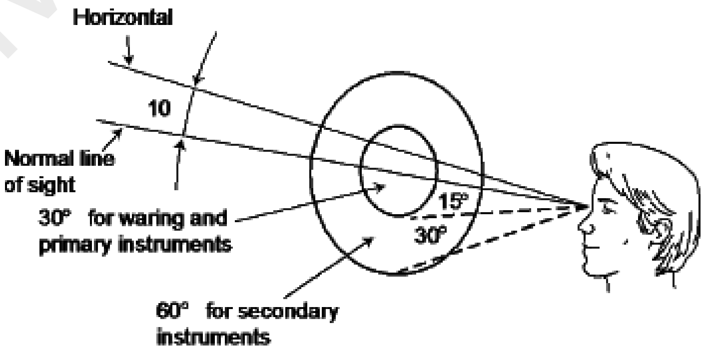


Figure 2: Positioning of visual instrument
(Source: Ivergard and Hunt, 2009, P.161)

Picture 2 indicate initial reference of visual position in the consideration of developing the interaction of human eyes and instruments. On the other hand, information ergonomics is the type covering the operating control panel activity to adjust the controlled operation observed from the display. It means that information ergonomics focuses throughout the entire system on the information flow resulting in the actual industrial and business processes. Usability support for operators to improve control center work efficiency by adjusting information management devices to fit their working behavior and capabilities (Gatto, Mol, Luquetti, Legey, & Carvalho, 2003).This issue therefore concerns their physical and psychological limitations. The following Figures 3 are some of the most important criteria for designing control systems and supporting devices.

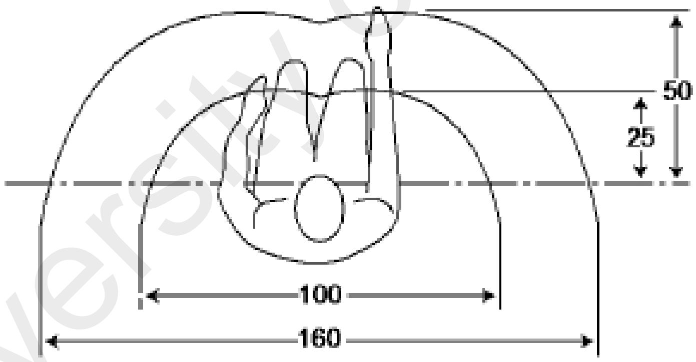


Figure 3: Visual measurement for a horizontal working surface
(Source: Ivergard and Hunt, 2009, P.161)

2.3 Ergonomic simulation

Computer technology advancement and the turning point of virtual reality technology with computer-aided design (CAD / CAE / CAM) technology has become one of major contribution in reducing gap between design and real world application. This advancement, it provides an opportunity for new techniques of ergonomics simulation to be explored and gradually moved from calculation thru all the theoretical formula, empirical data accumulation and simple implementation (Zhang & Chaffin, 2005).

Several tools and methods allow designers to reach significant target in the work place or workstation design. In many cases the efforts are focused on designing new solutions to get the best fitting with operation requirements. Also several tools implemented in current software for the integrated design are dedicated to assure designers creativity. A different approach is necessary for the design from an existing control centre to assure a better flexibility during the operating phases and to introduce ergonomic requirements(Lee & Cha, 2019).

One of the selection in introducing ergonomic simulation is using Digital human modelling techniques. This simulation have been developed to assist ergonomic design and evaluation for a specific worker population. Digital human modelling provide opportunity and availability to the engineers in developing a product that can consider ergonomics and human factors early in the development process (Berlin & Adams, 2017).

This simulation provides a 3D visualization of people involved in activities and provides information for ergonomic analysis and workstation design. Based on the visualization, the DHM increase the ability to provide live simulation and can even make it obsolete the need of the production of real prototypes. DHM is also increasingly being used by industrial manufacturers to simulate operator in computer simulations of new plants or processes (Satheeshkumar & Krishnakumnar, 2014). A discrete simulation of events models a system's operation as a separate sequence of time events. Each event will take place in time at a specific moment and marks an improvement in the system's state.

In addition, the continuous simulation of a computer model and the physical system, continuously tracks system response which one of the advantage of a DHM. Based design of the ergonomic evaluation of the workstation made it possible even at the early stages of the design process without the need for direct human subject measurements. (Harari, Bechar, Raschke, & Riemer, 2017) DHM also provide advantage in term of common capabilities and functions include moving manikins in predefined motions such as Rapid Upper Limb analysis (RULA), posture and reach analysis, push/pull analysis and load carrying analysis.

Rapid Upper Limb Analysis and 3D manikins are scale-up by using available anthropometry data. By importing the available human anthropometry data interface with the product design development is driving research brings ergonomics to a feasible stage (Blomé, Lundh, Hanson, & Högberg, 2015). This can be particularly replicate in the design of railway products and the ergonomics analysis of control centre tasks.

CATIA V5 is one of the available software that can deliver DHM. CATIA V5 provides a variety of efficient ergonomic analysis tools and processes that can analyze all factors in the HMI processes extensively and provide extensive ergonomic design solutions for designers(Ye, Li, & Li, 2013). Since the use of control center as operating systems, this will involves a wide range of body sizes, for each size of the digital human model, the best use of performance between humans and control center must be taken into consideration (Md Deros, Mohamad, Rasdan Ismail, & Nazeer Muhammad Nazree, 2009). CATIA V5's ergonomic applied research platform establishing a virtual human body model and specific control center.

CATIA V5 has been one of the available DHM delivery software. CATIA V5 offers a wide range of efficient in ergonomic analysis tools and procedures that can extensively evaluate all variables in HMI processes as well as provide designers with extensive ergonomic technical solutions. Because the use of actual dimension of operating systems it requires a wide range of body sizes. Thus actual human anthropometry is used to replicate the best performance between humans and control center interfaced (Luquetti dos Santos, Farias, Ferraz, Haddad, & Hecksher, 2013).

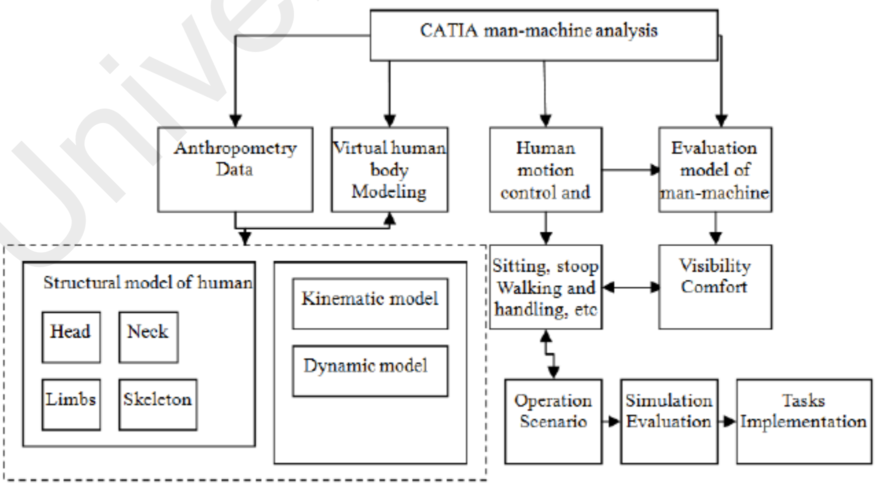


Figure 4: CATIA process flow

2.4 Rapid Upper Limb Analysis (RULA)

RULA was developed to evaluate individual exposure to ergonomic factors that increase associated with upper extremity. The RULA ergonomic evaluation tool takes into consideration the biomechanical and postural load requirements of the job tasks. Besides, it also take the consideration of neck constrain, trunk and upper limbs. RULA allows parameters between manikin and the workstation such as distance, height and frequency would be used to evaluate the upper limbs of manikin (Kusnandar & Noya, 2013). CATIA V5 applicable to replicate many aspects of manikin posture depending on required human anthropometry on different variables data and posture. It takes care of specific work variables such as external support for the manikin, the manikin balance and the manikin's arms orientation with reference to the body and feet (Kabilmiharbi & Selamat, 2016).

RULA score shows acceptability of task and posture based on the manikin loaded. The suggested task or posture will be analyze and result will show does it acceptable or should be further investigated or require design changes immediately (Kale & Vyavahare, 2016). The postural result is targeting the method which estimating the risks of upper limb disorders associated with the work. Action levels of RULA predict the seriousness of the need to change how a person works depending on the degree of risk of injury. CATIA V5 software performs RULA analysis by providing wide range of body posture, force, and repetition in a single page worksheet (Umar et al., 2018). Figure 5 show how the RULA score being tabulated and analyze to produce the result which can determine the simulated posture.

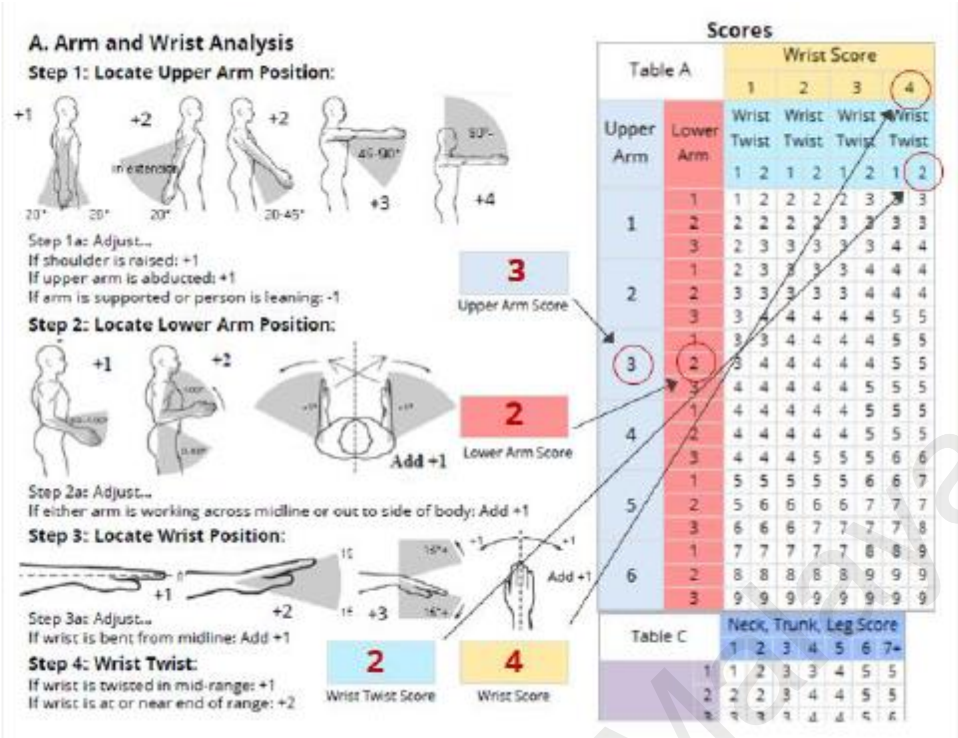


Figure 5: RULA Score of arm and wrist analysis

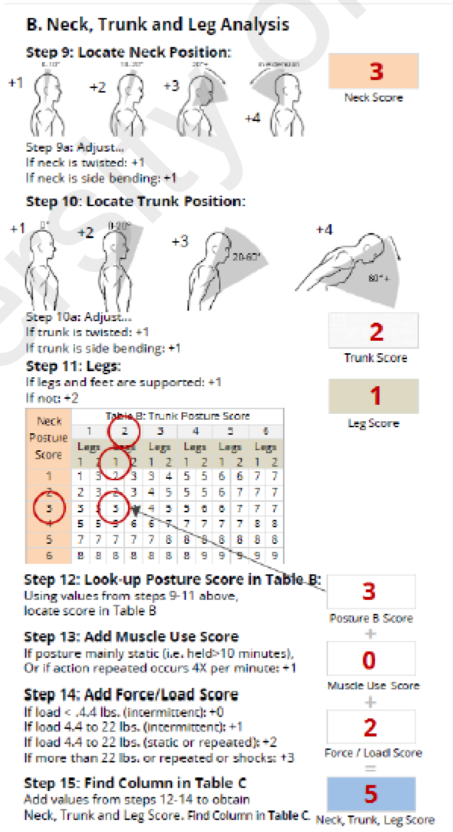


Figure 6: RULA Score of neck, trunk and leg analysis

CHAPTER 3

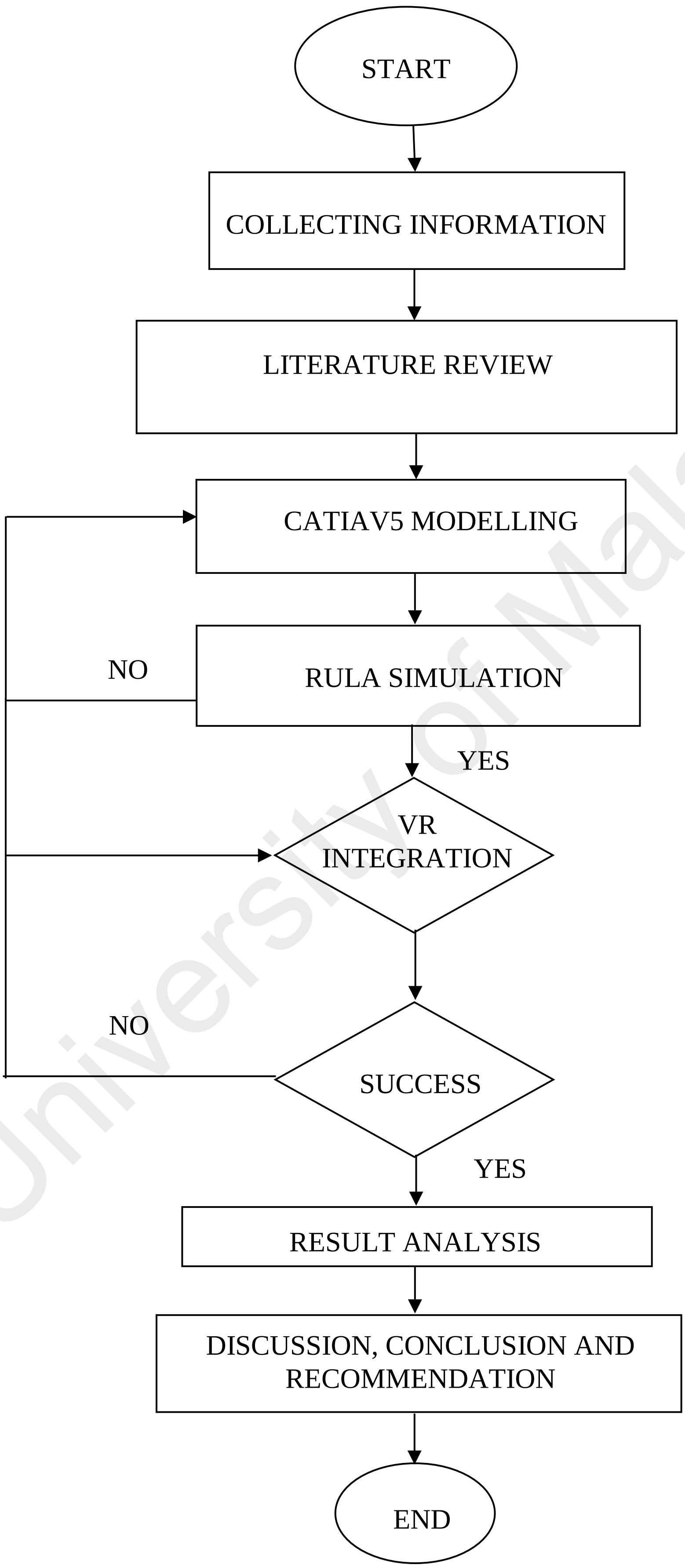
METHODOLOGY

3.1 Introduction

The research involves multidisciplinary technical understanding that incorporates different computer-aided data process planning expertise, modeling of human posture, and identification of ergonomics simulation based on reference drawing. The main deliverable research in the thesis is to develop and apply CAD modeling and simulation integration with Virtual Reality technologies to the correct ergonomics analysis in the operation of the control center.

Sample reference of OCC from one of Malaysia railway industries has been develop by several conversion of commercial software tool. This method were selected to ensure the modelling of control center workstation is accurate as per reference drawing. Next is to develop the human modelling is adopted for the integration with RULA ergonomics simulation. The human model will be based on 95^{th} percentile Malaysia Man Anthropometry. Besides, the association with the Virtual Reality capabilities in the real time simulation ergonomics solution help a series of human related issues in the operational task process is simulated and studied in order to demonstrate the benefits of a RULA and virtual approach to the workplace design.

Flow chart


START
COLLECTING INFORMATION
LITERATURE REVIEW
CATIAV5 MODELLING
NO
RULA SIMULATION
YES
VR
INTEGRATION
NO
SUCCESS
YES
RESULT ANALYSIS
DISCUSSION, CONCLUSION AND
RECOMMENDATION
END

3.2 Developing the Operation Control Center (OCC)

In the development of the OCC model, the sample Operation Control Center room has been obtain from one of the Malaysia railway industries. The layout and the equipment location are almost similar based on the existing design. In this research, the layout and equipment arrangement has to be alter due to security and safety concern that require the model to be further develop. The alteration will not compromise the ergonomics study of this research.

The first step on developing model or extracting model based on current design is by developing the Revit model using Autodesk Revit software. The Revit model comprise the architecture model, mechanical model and system equipment model. Figure 4. Show the sample of Revit model that comprise all related model that show complete OCC layout.

Revit Model:

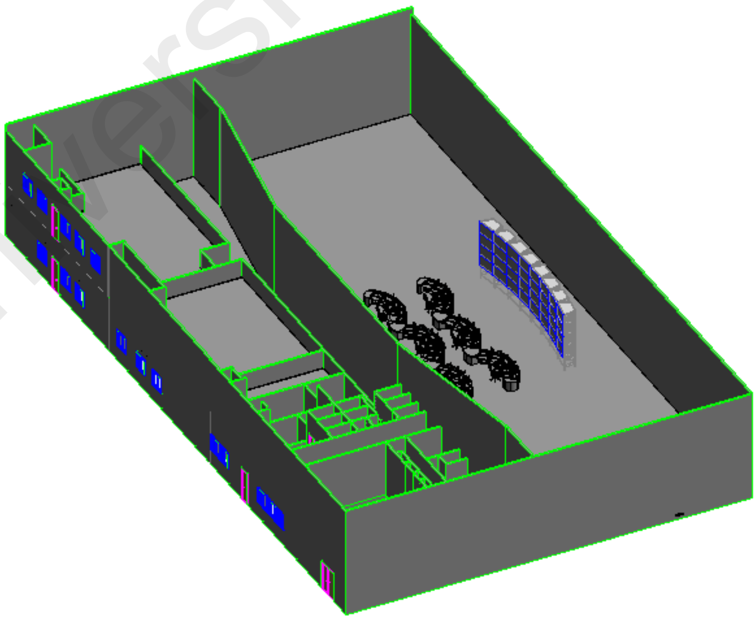


Figure 7: Architecture model

Figure 5 show the overview of console table and the mimic panel display of the OCC which will be further develop in CATIA V5 model for ergonomics analysis.

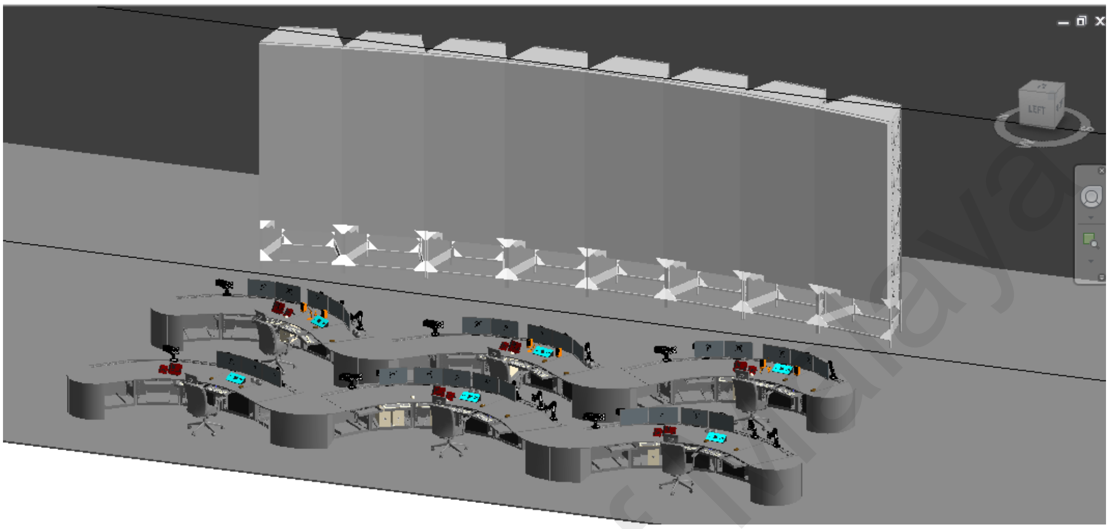


Figure 8: 3D view of OCC model

Figure 9: Front view of Mimic Display

Based on the Revit Model and the reference drawing of OCC. The Autodesk AutoCAD layout has been develop produce the detail drawing that will be use to model the exact dimension of console table which will be used in CATIA V5 modelling. Beside the AutoCAD model, the typical console detail also been obtain from the reference drawing.

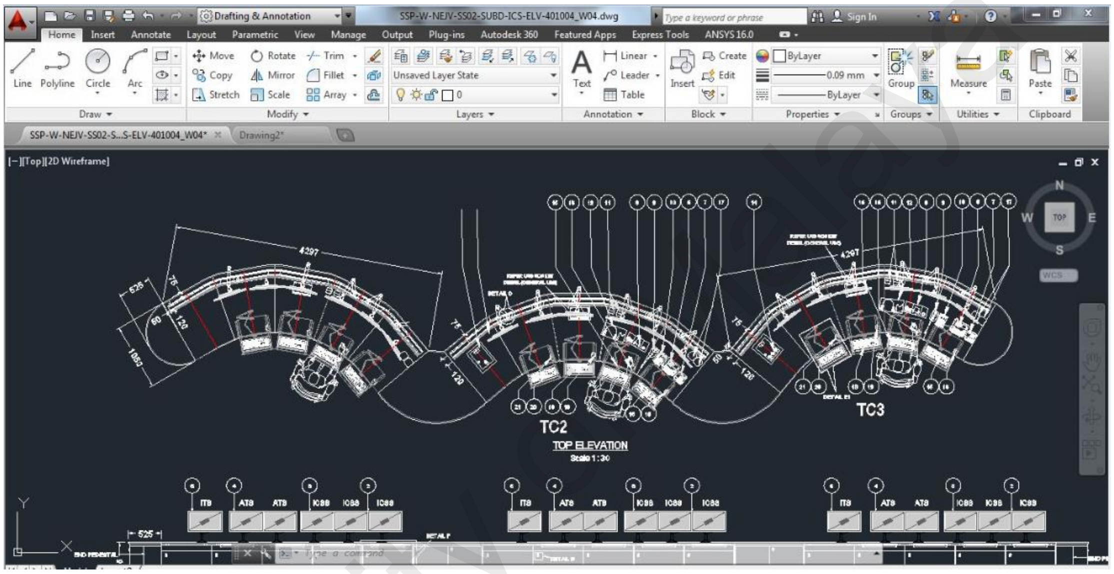


Figure 10: Plan layout of operation control center

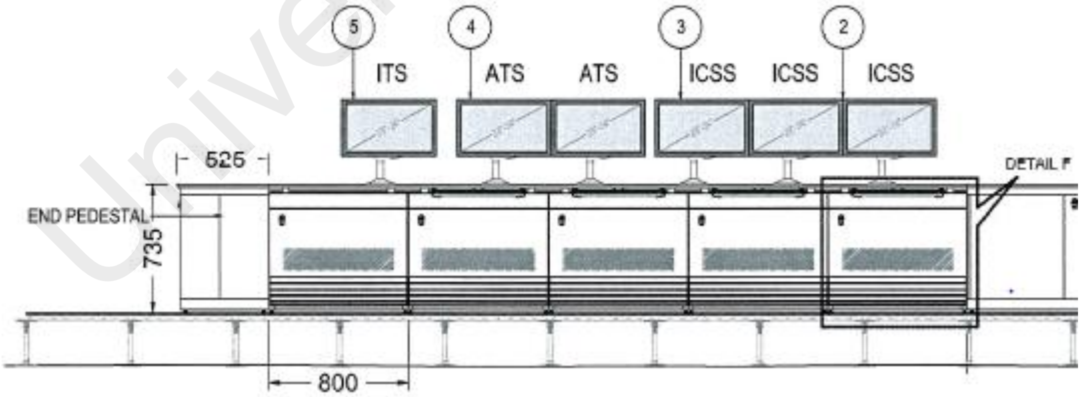


Figure 11: Typical monitor layout of operational control center

Based on the plan layout, the Autocad drawing of the console table are being extracted to single individual console table. This step is to provide a common sample of console table that require to be model in CATIA V5.

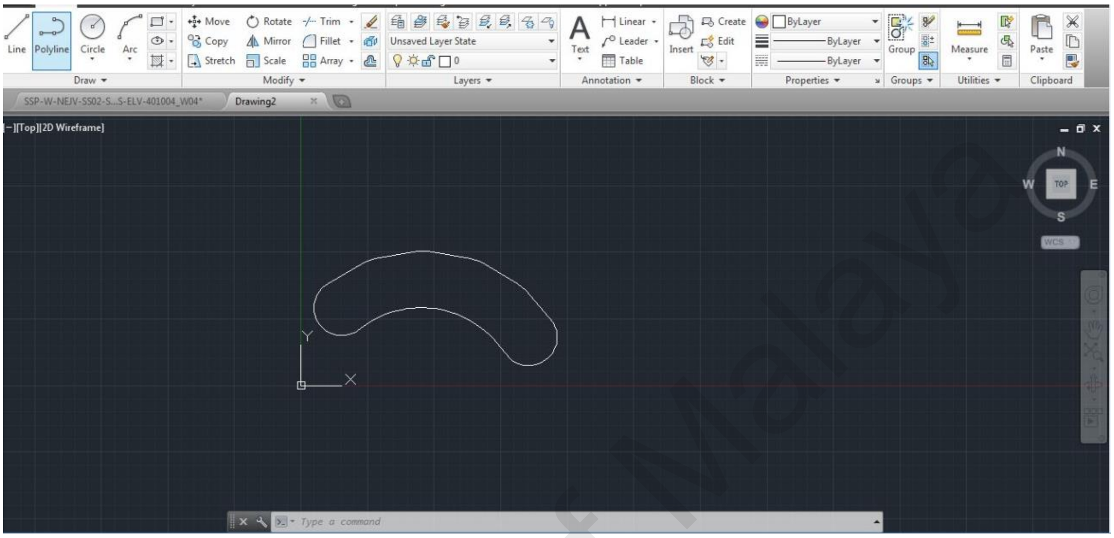


Figure 12: Extract AutoCAD drawing of console table

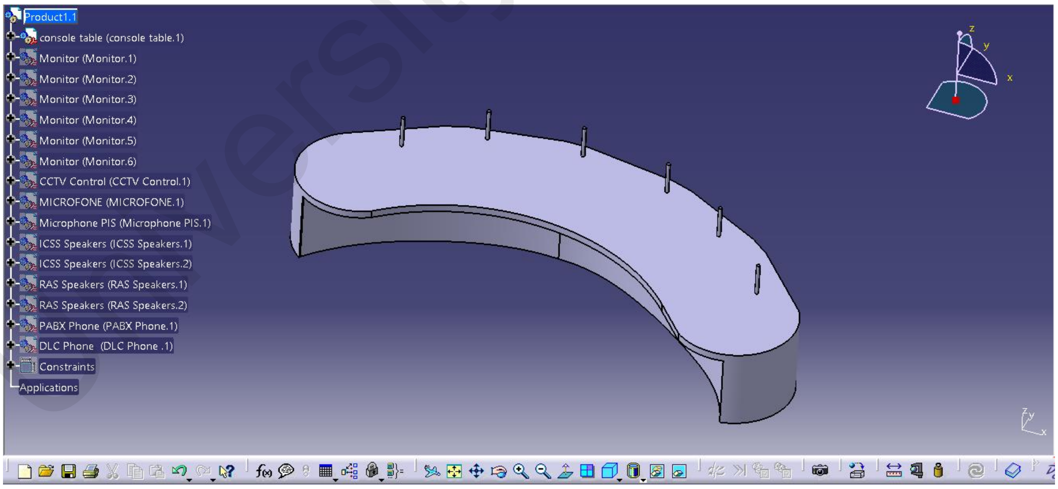


Figure 13: Console table in CATIA V5

With the base model of console table has been completely model as per exact dimension. The next process is to arrange the equipment require for operation based reference layout which can be seen on Figure 8, 9 and 12.

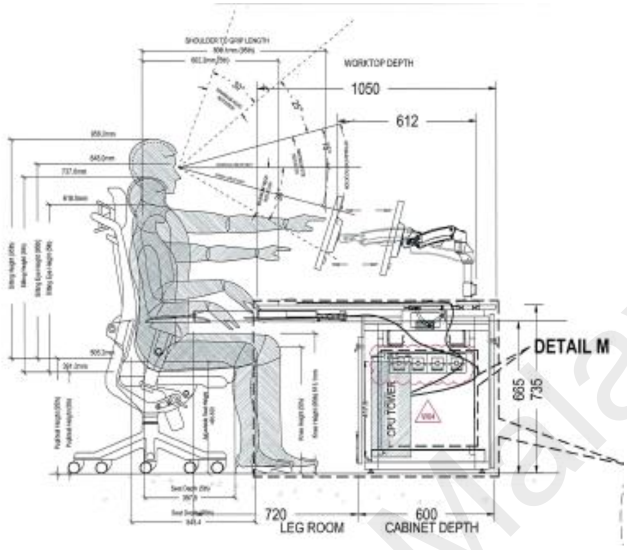


Figure 14: Typical dimension of equipment arrangement

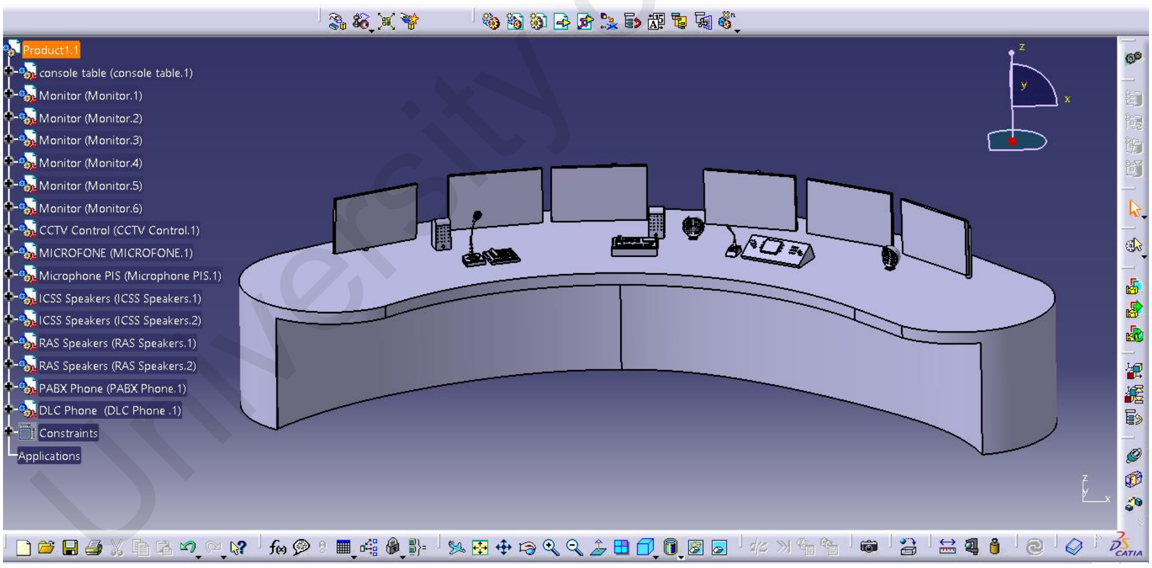


Figure 15: CATIA V5 equipment arrangement

Due to safety and security concern, the CATIA V5 equipment arrangement has to be slightly alter. The distance of workstation are still following the exact reference drawing.

3.3 Developing the Human ergonomic simulation in CATIA V5

The human model was taken based on 95th percentile Malaysia Man Anthropometry (Mohamad, Deros, Ismail, Darina, & Daruis, 2010) which data obtain from 1,007 Malaysian consisting of 516 males and 491 females. The chosen subject and anthropometry data is tabulated in Table 1. The subject was selected for this study had to perform RULA analysis in order to identify the subject's exposure towards conducted posture.

Table 1: Anthropometric data for the overall Malaysian citizen, all units are in mm

(Mohamad et al., 2010)

No	Anthropometric Dimensions	Mean	SD	5th Percentile	95th Percentile
1	Stature	1565.00	59.58	1466.69	1663.31
2	Eyes Height	1451.15	100.52	1285.29	1617.01
3	Sitting Height	792.86	76.20	667.12	918.59
4	Hand Length	173.37	15.24	148.22	198.52
5	Sitting Eyes Height	679.08	72.69	559.14	799.01

The body generic model:

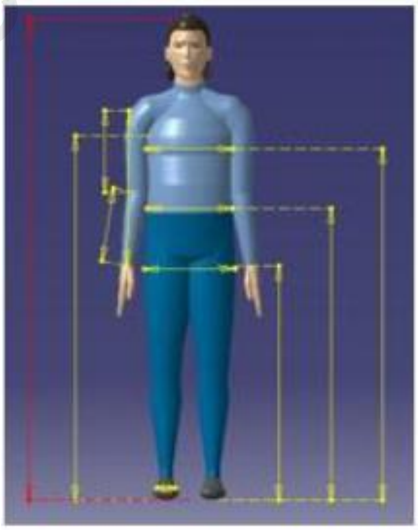


Figure 16: Sample human model

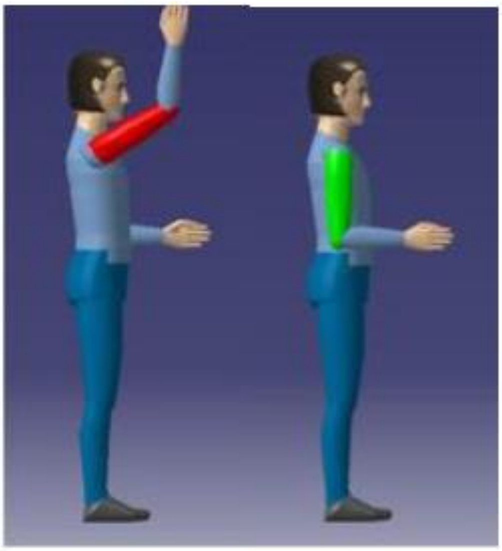


Figure 17: Sample movement of human model

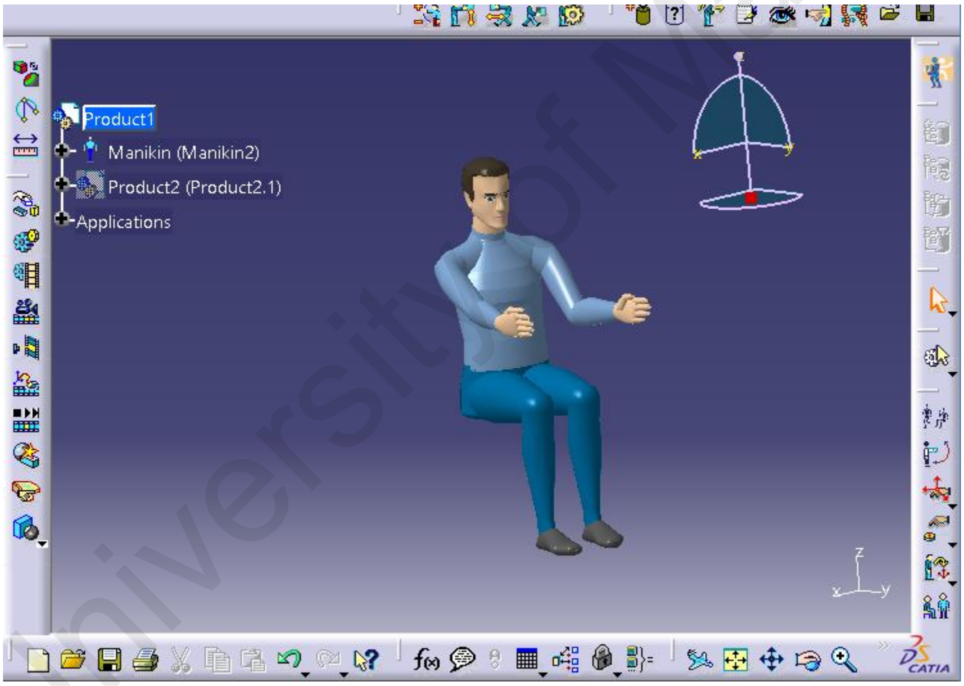


Figure 18: Sample model of sitting position

As for the development of RULA simulation, the human generic model has been attached to the operation control console table.

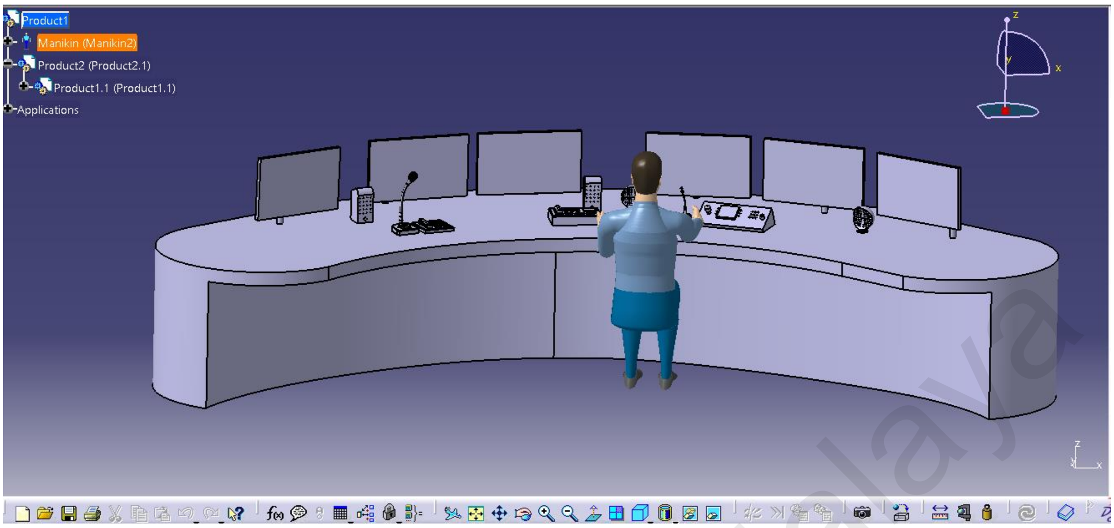


Figure 19: Attachment of manikin model to console table

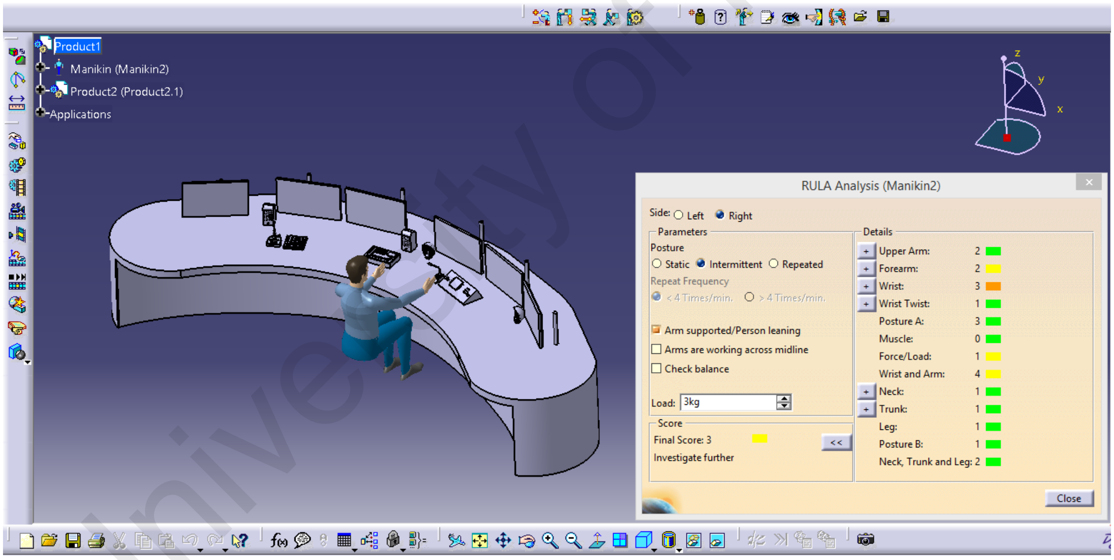


Figure 20: RULA analysis of right side of manikin

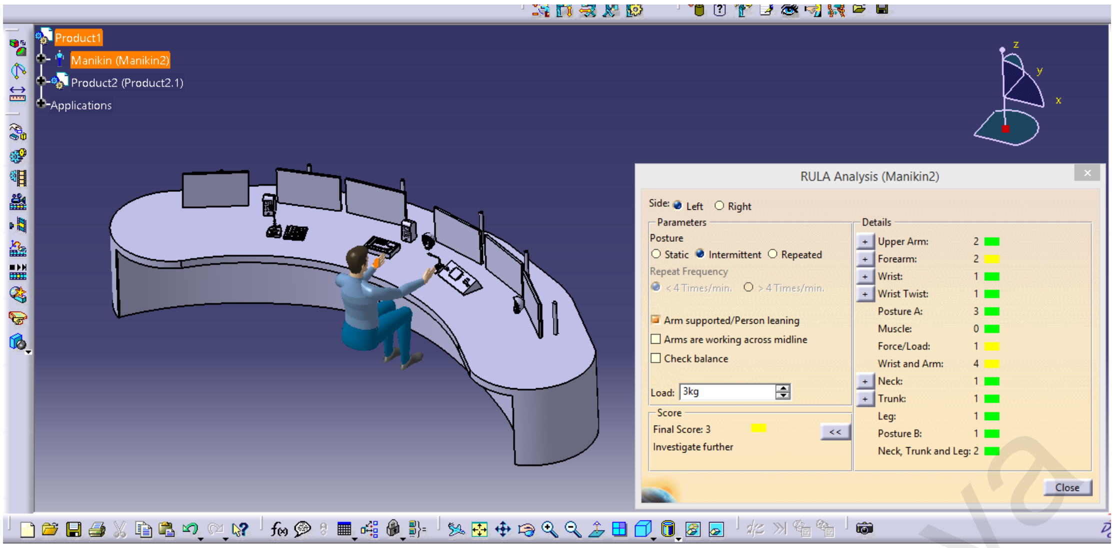


Figure 21: RULA analysis of left side of manikin

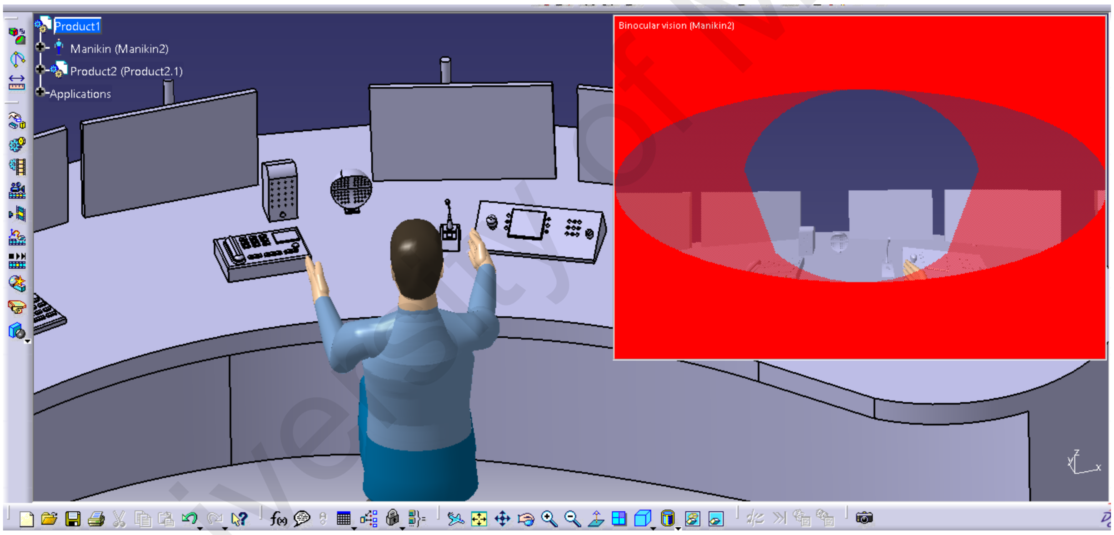


Figure 22: Manikin eye level view

The manikin has been develop based on the 95th percentile of Malaysian because, most of the operator involve in operation control are in the range of 95th percentile. Besides that, age factor of the operator are in between 27 – 39 which are more close to the 95th percentile of Malaysia person.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

RULA analysis was performed after being modeled using CATIA V5. Based on the model, there were 5 postures has been demonstrate which posture probably replicated the operational movement. The manikin subject's assigned positions will be reflect on the RULA results. The first posture, shows the movement of right and left arm on reaching the equipment on top of the control center. Posture 2 is where the subject replicated the reaching of hand on much further equipment. After that, posture 3 is where the subject have to move a bit to the left side of the control table to observe the most left monitor. 4th posture is the movement of shoulder and neck. Finally, position 5 shows the subject movement of palm and wrist.

4.2 Parameter Observe and discussion

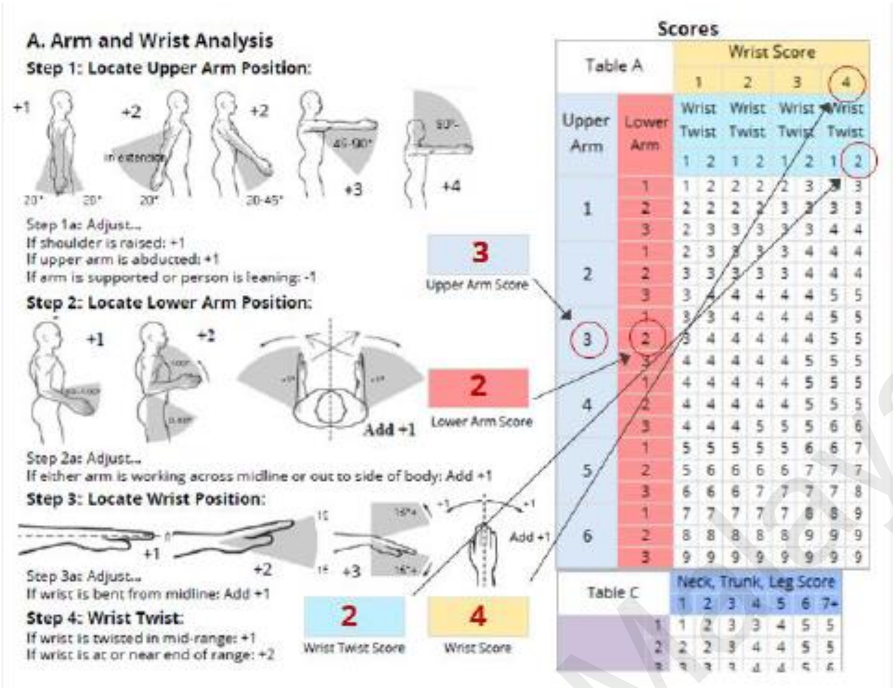


Figure 23: RULA Score of arm and wrist analysis (Umar et al., 2018)

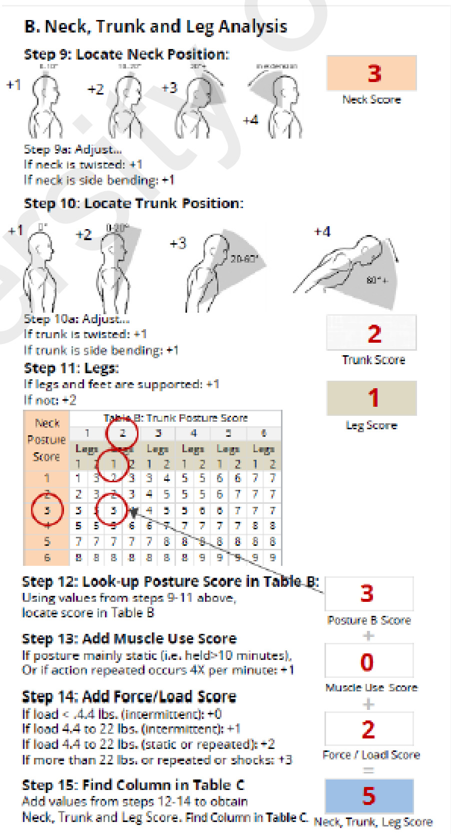


Figure 24: RULA Score of neck, trunk and leg analysis (Umar et al., 2018)

Based on Figure 5 and 6. Result of Both Posture A score Posture B score data will be combine and evaluated from using Figure 23.

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

Figure 25: Final score of RULA analysis

Table 2: Final RULA score

Posture	1	2	3	4	5
Posture A score (wrist and arm)	3	2	3	4	2
Posture B score (neck, trunk)	3	3	4	2	2
Final score	3	3	4	3	2
Color					
Action	Low risk, change to be consider	Low risk, change to be consider	Low risk, change to be consider	Low risk, change to be consider	Negligible risk. No action required

Based on the result obtain from the RULA analysis, the posture 1 indicate that the low risk of injury. When the manikin been subjected to frequency of 4 movement in one minute, result show good ergonomics design of the control center as minimum change require for the reaching location of equipment. The posture 2 result also show that, when the manikin replicated the reaching of hand on much further equipment low risk of injury also may subjected based on the action. This is because, the shape of an oval help to reduce the distance of equipment. The availability to reach adjacent equipment in same frequency indicate in long term of working condition, the design still only produce less effect to MSD.

As for posture 3 is where the subject have to move a bit to the left portion of the control table to observe the most left monitor. The RULA analysis show slightly higher result compare to previous movement. The might result from the need of the manikin to move first before reaching up the most left monitor. Similar pattern of movement repetition also show similar result which this may consider one of the factor that cause MSD for long term operation. From this result, the most left monitor should be the least function workstation among other monitor. This will help to reduce the movement of operator to that workstation and less MSD effect for long term operation.

Next movement was the movement of shoulder and neck. RULA analysis show low risk of injury as the movement of shoulder and neck are not big. Based on current anthropometry of minor change may need in term of chair level or monitor level. This can be counter by the usage of adjustable chair height.

Finally, position 5 shows the subject movement of palm and wrist. The simulated result show very low risk of injury. RULA analysis also show the risk can be negligible risk and no action required in term of console design. As the equipment size and location are fit the purpose and not require any extra movement.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The computer-aided control center design research based on man-machine interface mainly analyzes issues of whether the products meet Malaysian human anthropometry size requirements. Based on the RULA result obtain, with referencing on 95th percentile of Malaysia human anthropometry, posture 1 conclude that the reaching position still can be optimize. As for posture 2 and 3, the significant movement conclude that the major physical movement contribute higher RULA result. Based on this research result, the product design and operating requirements are reasonable can be simulate by applying the CATIA V5 – RULA analysis module, which give direct numerical result which give better understanding on the optimizing the product design and human interface. The simulation shows that the entire human body and postures can be repeatedly, extensively and systematically analyzed from different aspects. To increase better prospect in term of simulation analysis, the function of virtual reality also has been tried in this project. This help further to evaluate the comfort of the user based on virtual sample to check and feel the control center environment.

5.2 Recommendations

To be further expanded, the actual personnel should test the design of the operation control center. This can validate the result obtain from the RULA's applications and extensively gather actual data to be investigate. The individual posture scores indicates which aspects of the postures are likely to be ergonomics compare to the software analysis. There is still a need further substantiation of this project and can be perform to obtain the closes accuracy between RULA and actual scores.

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