PRODUCTIVITY IMPROVEMENT THROUGH RE-DESIGN WORKPLACE AREA

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Mechanical Engineering (Pure)

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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "Productivity Improvement through Re-design Workplace Area" is written by Lim Tien Yong. I have examined the final copy of this project and in my opinion, it is fully adequate in terms of language standard and report formatting requirement for the award of the degree of Bachelor of Mechanical Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

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I hereby declare that I have checked this report and in my opinion, this report is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project report "Productivity Improvement through Re-design Workplace Area" is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not contently submitted in candidate of any other degree.

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ABSTRACT

For industrial use, ergonomics has traditionally been used to solve the injuries problem from repetitive motion, prolonged postures, and some other physical risks. However, the utility of ergonomics is not just only limited to solve the injuries problem. Good ergonomics investment also can be applied to improve productivity. This project are carried out at Sidmann Composite Sdn Bhd. The Objective of this project are propose a new workplace with ergonomics features for Sidmann Composite Sdn. Bhd. to reduce the level of musculoskeletal risks of the workplace and improve the production process's cycle time. In order to ensure the objectives are met. A comprehensive data collection was divided into three phase, such as phase one is to perform up-front analysis, phase two is to determine the existing working process risk and operational impact, phase three is to estimate proposed working process risk and operational impact. The assessment was carried out by Rapid Entire Body Assessment (REBA) and Strain Index (SI) to assess the level of musculoskeletal risk in this company. Methods-Time Measurement (MTM) was used to determine the labor time for the performing task improvement. Finally, existing process and proposed process was compared in this project.

ABSTRAK

Dalam sektor industri, ergonomik secara tradisinya telah digunakan untuk menyelesaikan masalah kecederaan dari gerakan berulang-ulang, postur yang berpanjangan, dan beberapa risiko fizikal yang lain. Walau bagaimanapun, utiliti ergonomik tidak hanya terhad untuk menyelesaikan masalah kecederaan, aplikasi ergonomik yang sesuai juga boleh meningkatkan produktiviti. Objektif projek ini adalah mencadangkan tempat kerja baru dengan ciri-ciri ergonomik untuk Sidmann Komposit Sdn. Bhd untuk mengurangkan tahap risiko otot tempat kerja dan meningkatkan masa kitaran proses pengeluaran. Kaedah yang digunakan untuk menjalankan projek ini berlaku dalam tiga fasa. Fasa 1 adalah melaksanakan analisis awal, fasa 2 adalah untuk mencari risiko kesakitan otot yang ada semasa berkerja dan kesan operasi tugas, fasa 3 adalah menganggarkan tahap risiko kesakitan otot semasa berkerja dan kesan operasi tugas. Reka bentuk tempat kerja baharu akan dijalankan sebelum memulakan fasa 3. Rapid Entire Body Assessment (REBA) and Strain Index (SI) akan diguna untuk menilai tahap risiko kesakitan otot semasa bekerja dalam syarikat ini. Kaedah Pengukuran Masa (MTM) akan digunakan untuk mencarikan masa bekerja semasa melaksanakan tugas. Akhirnya, proses yang digunakan sekarang akan digunakan untuk menbandingkan dengan proses yang dicadangkan.

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LIST OF SYMBOLS

in	-	Inch
TMU	-	Time measurement unit
s	-	Second
cm	-	centimeter
REBA	-	Rapid Entire Body Assessment
SI	-	Strain Index
OCRA	-	The occupational Repetitive Actions
QEC	-	Quick Exposure Check

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ergonomics derived from Greek, ergon (work) and nomos (laws) to denote the science of work, ergonomics is the scientific discipline concerned with the understanding of the interactions between humans and work. There are three types of ergonomics, such as Physical ergonomics, Cognitive ergonomics, and Organizational ergonomics. The type of ergonomics that study in this final year project is Physical ergonomic, this study is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as related to physical activity.

For industrial use, ergonomics has traditionally been used to solve the injuries problem from repetitive motion, prolonged postures, and some other physical risks. However, the utility of ergonomics is not just only limited to solve the injuries problem. Good ergonomics investment also can be use to improve productivity.

1.2 Background of Study

Ergonomics isn’t just a catchy buzz word. Ergonomics is a kind of science. The history of ergonomics can started with the ancient Greeks. There is evidence that the Greeks was used principle of ergonomics as early as the 5th century BC.

In the 19th century the 'scientific management'; method was introduced by Frederick Winslow Taylor. This method was aimed at increasing the efficacy of a worker by improving the process of the task. For example, Taylor found out that by reducing the weight and size of coal shovels, the amount of coal being shoveled by workers could be tripled. These ideas led to reduced work injuries and an increase in production levels. This indicates the use of basic ergonomic concepts at that time.

In the 20th Century and Beyond, ergonomics is start become formalized to fit the soldiers needs during the World War II. The military use ergonomics principles to design equipments and weapons. A notable case involved Lieutenant Alphonse Chapanis redesign of aircraft controls with ergonomics features, he was able to increase control panel ease-of-use and reduced the number of crashes that had.

An industrial survey that conducted by Ali et al. (2001) in the Kinta Valley area in Perak state discovered some interesting findings, none of those interviewees had taken ergonomics or human factors engineering courses during their study, they was no knowledge of ergonomics linkages to industrial safety and health.

In a recent study on ergonomics awareness in Malaysian manufacturing industries by Mustafa et al. (2009), they discover about that 35.6% of Malaysian manufacturing industries have a high level of ergonomics awareness and 33.3% of the manufacturing industries implemented ergonomics programs. Among those ergonomics programmes implemented, orientation was mostly used (44.4%) and proves the most effective.

From above, we can know that ergonomics is getting famous now in Malaysia to use in workplace area like factory, office, school, and other more. By investing ergonomics in office furniture and other working environments, we can learn from ancient Greek's wisdom to implement in nowadays ergonomics to increase productivity, increase comfort, and decrease musculoskeletal risks.

1.3 Backgrouond of Company

Sidmann Composite Sdn Bhd formerly known as Sidmann Tank Sdn Bhd was a company that doing business on fabricate and supply Fiberglass composite product. The company is a project-based business, providing product design and fabrication following the customer's requirement. Since the company is a project-based business, most of the works of fabrication was doing manually by hands. This project was carried out to help to improve the workplace environment for manual work workplace to improve productivity and reduce working musculoskeletal risk. Logo of Sidmann Composite Sdn. Bhd. was showed in Figure 1.1

Figure 1.1: Sidmann Composite Sdn. Bhd. logo

1.4 Problem statements

Ergonomics has traditionally been used to reduce the number of occupational injuries by discovering those postures and tacks that create significant musculoskeletal stresses. However, the principles which underlie ergonomics can potentially be used to improve productivity as well. Ergonomics guidelines may allow prediction of those postures and workplace layouts that maximize the speed at which employees can work.

The study for the project will be carried out at Sidmann Composite Sdn. Bhd. From the observation at workplace showed in Figure 1.2, productivity is not at the optimum level due to lack of ergonomics features. The company is also lack of ergonomics expert, they also lack of experience on ergonomics investment, this problem may cause them experience a lot of wastes on their organisation.

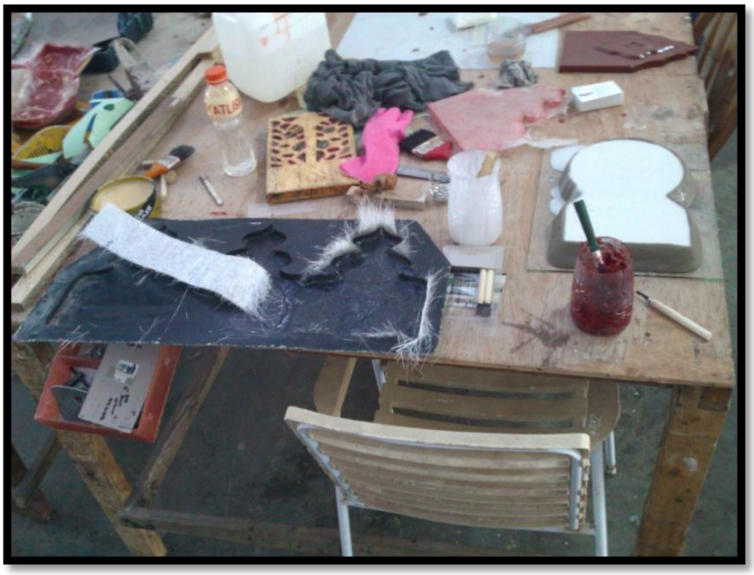

Figure 1.2: Working environment in Sidmann Composite Sdn. Bhd.

1.5 Project Aim and Objectives

There are three objectives for this project,

i) To propose a new work place with ergonomic features for Sidmann Composite Sdn. Bhd.

ii) To reduce the level of musculoskeletal risks of the workplace.

iii) To improve the production process's cycle time.

1.6 Project scopes

This project is carried out at Sidmann Composite SDN. BHD. The study comprise of three element,

i) To study the predetermined time technique used in function task analysis.

ii) To implement ergonomics knowledge in workplace area layout design.

iii) To study the relation between ergonomics and productivity.

CHAPTER 2

LITERATURE REVIEWS

2.1 Workplace working postures

The meaning of ergonomics is the laws of work. Scientific was discipline that ergonomics is the interaction between the person and their working place. There was also got some injuries due to poor ergonomics, commonly caused by repetition and over strain at tendons and joints, unbalanced and prolonged postures, and chronic(cyclic inflammation and weakness). Our human spine was divided into 5 areas, each vertebrae is separated by an inter vertebral disc. The inter vertebral disc was acted as shock absorbers. When we are working for a fixed posture, the disc was gradually pushed over time. It increased pressure on the back wall of the disc, and this will cause the back pain. Figure 2.1show that different postures will produce different inter vertebral disc pressures.

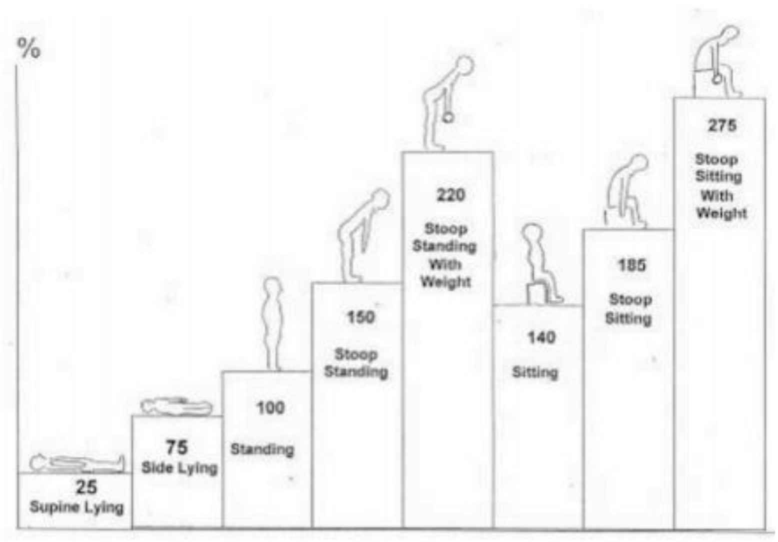

Figure 2.1: Inter vertebral Disc Pressures (Nechemson, 1960)

2.2 Standing Posture

Standing work can be categorized based on leg movements like dynamic activity and static activity. Dynamics activity was the activity that involved leg movement, and static activity was the activity with no leg movement or with standing posture. The person need or want to stand while working at their working place. To be ergonomics, an appropriate desk can be designed and selected for the type of work they performed. According to Grandjean (1997), the desk height for a standing person can range from 28-43" depending on what they work performed, either is for precision, light, or heavy work. Figure 2.2 show that different work surface heights can be used depending on the type of work performed.

Different task require different work surface height,

i) Precision work, 5cm above elbow height.

ii) Light work, 5-10cm below elbow height.

iii) Heavy work, 20-40cm below elbow height.

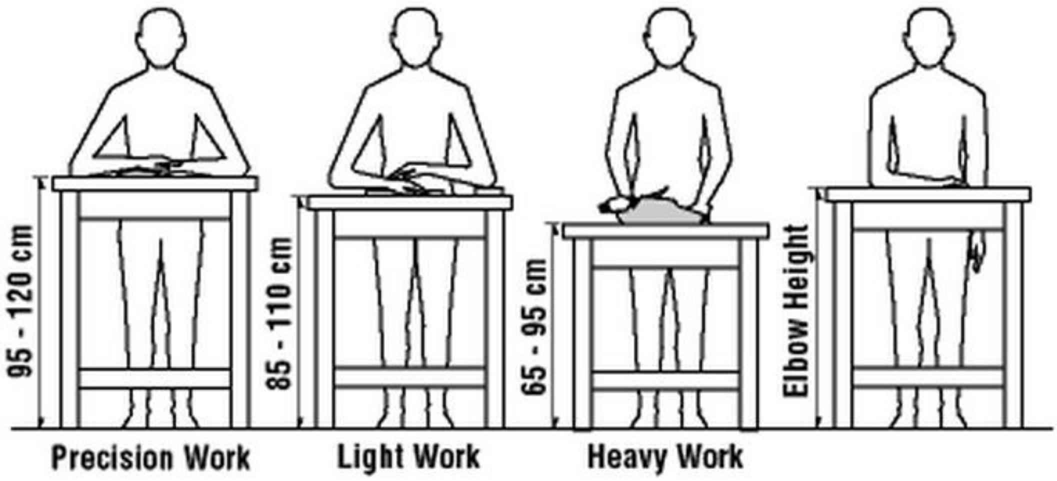

Figure 2.2: Different work surface heights can be used depending on the type of work performed

2.3 Common Workplace Motions

The workplace should be comfortable and adapt to needs as much as possible. A good workplace design should in mind can lead to higher the person productivity and also reduce the risk of injury and illnesses. In Figure 2.3, there are 4 Zone that user might encounter while working:-

i. Zone 0 (Green Zone)
   Preferred zone for most movements. Puts minimal stress on muscles and joints.
ii. Zone 1 (Yellow Zone)
   Preferred zone for most movements. Puts minimal stress on muscles and joints.
iii. Zone 2 (Red Zone)

More extreme position for limbs, puts greater strain on muscles and joints.

iv. Zone 3 (Beyond Red Zone)

Most extreme positions for limbs, should be avoided if possible, especially with heavy lifting or repetitive tasks.

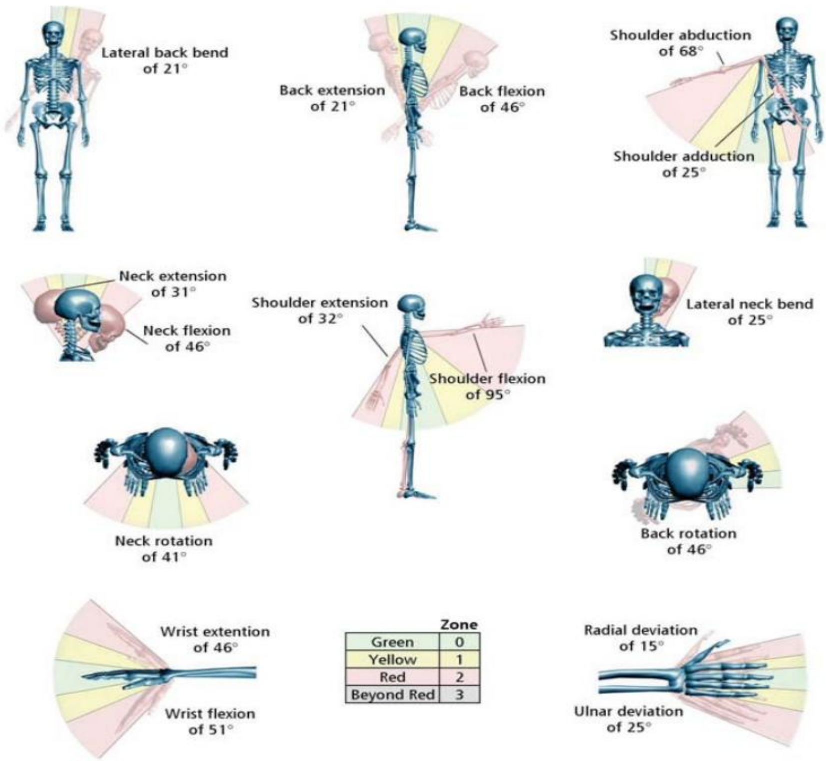

Figure 2.3: Various ranges of motion for different joints

Source: Ergonomics and Design, A Reference Guide [Scott Openshaw and Erin Taylor, 2006]

2.4 Standing Workstation Design Principles

The design of workstations have to demonstrate minimal physical stresses to the worker that may lead to localized fatigue, pain and uncomfortable to the worker.

i. Re-design task to allow worker to sit or stand whenever necessary to do so.
ii. Provide workstation accessories like A cushioned surface to stand on, Adjustable working surface, and other suitable accessories.
iii. Arrange for task variation so that worker can perform different tasks so that allow the legs to move to reduce static loading.
iv. Job or employee rotation.
v. Introduce frequency short breaks for worker to recover from fatigue during working.
vi. Proper and sufficient lighting. The required lighting must varies for general work and close-up work. Postures may be affect the light intensity when worker doing the close-up work, so have to make sure that proper lighting is designed for worker to do general work and close-up work.

Source: Ergonomics and Design, A Reference Guide [Scott Openshaw and Erin Taylor, 2006]

Optimal working postures was a critical factor to achieve work efficiency and human well-being. With the simple rules described in Figure 2.4, it is possible to make a excellent workplace.

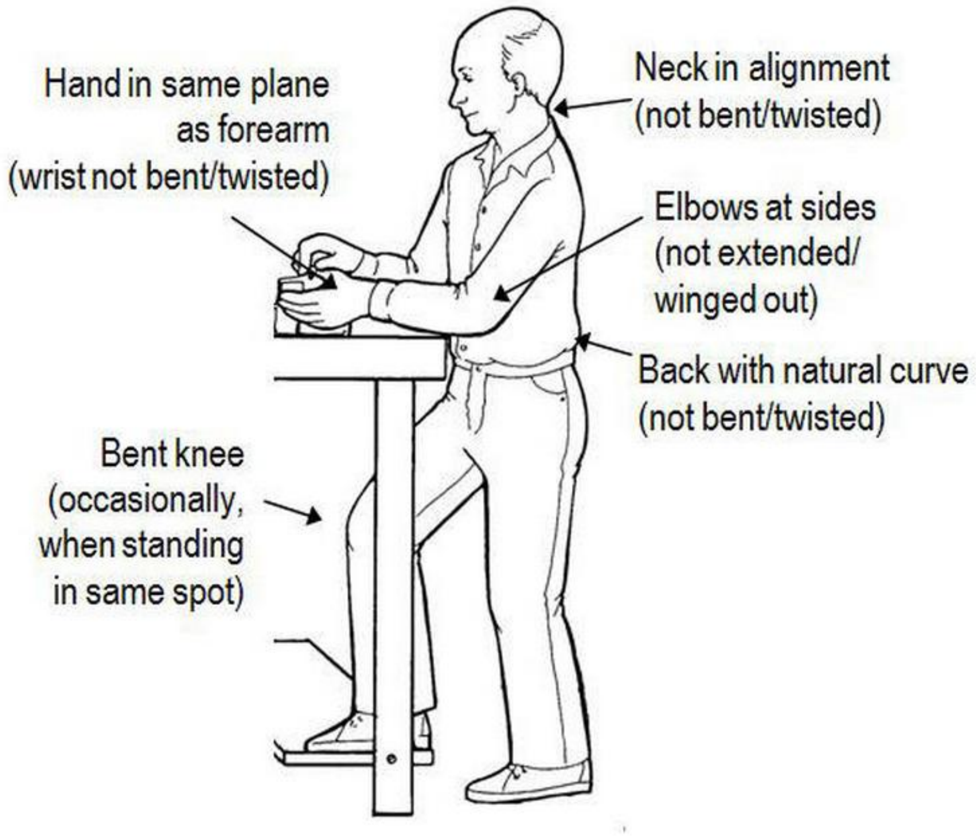

Figure 2.4: Optimal working position (Standing)

Source: Work in Optimal Position [Dan macLeod, Ergonomics consultant CPE, MA, MPH, 2012]

2.5 Examples of Musculoskeletal Disorders

Figure 2.5 shows the example of musculoskeletal disorders.

Body Parts Affected	Symptoms	Possible Causes	Workers Affected	Disease Name
thumbs	pain at the base of the thumbs	twisting and gripping	butchers, house-keepers, packers, seam-stresses, cutters	De Quervain's disease
fingers	difficulty moving finger; snapping and jerking movements	repeatedly using the index fingers	meatpackers, poultry workers, carpenters, electronic assemblers	trigger finger
shoulders	pain, stiffness	working with the hands above the head	power press operators, welders, painters, assembly line workers	rotator cuff tendinitis
hands, wrists	pain, swelling	repetitive or forceful hand and wrist motions	core making, poultry process-ing, meatpacking	tenosynovitis
fingers, hands	numbness, tingling; ashen skin; loss of feeling and control	exposure to vibration	chain saw, pneu-matic hammer, and gasoline-powered tool operators	Raynaud's syndrome (white finger)
fingers, wrists	tingling, numb-ness, severe pain; loss of strength, sensation in the thumbs, index, or middle or half of the ring fingers	repetitive and forceful manual tasks without time to recover	meat and poultry and garment workers, uphol-sterers, assem-blers, VDT operators, cashiers	carpal tunnel syndrome
back	low back pain, shooting pain or numbness in the upper legs	whole body vibration	truck and bus drivers, tractor and subway operators; ware-house workers; nurses aides; grocery cashiers; baggage handlers	back disability

Figure 2.5: Examples of Musculoskeletal Disorders

Source: U.S. Department of Labor Occupational Safety and Health Administration, 2000

2.6 Tools assessing Musculoskeletal Risk

There are two suitable tools that can assess in this project, Rapid Entire Body Assessment (REBA), and Strain Index (SI). In this two kind of tools, REBA is a tool that assess postural score for body (i.e. legs, trunk, neck.), and the upper distal extremities (i.e. upper arm, lower arm, and wrists.). SI is a tool that assessed a task's upper distal extremity (i.e. finger, hands, wrist.). These tools are designed to measure the type of musculoskeletal risk observed in operating tasks.

2.7 Rapid Entire Body Assessment (REBA)

REBA is a tool to assess the posture for risk of work-related musculoskeletal disorders (WRMSDs), it was proposed by Hignett and McAtamney,UK (2000). It is designed to provide a quick and easy observational postural analysis for whole body activities in health-care and other service industries.

The REBA score can be calculated by referring the instruction highlighted in Figure 2.6 to get the result from REBA Assessment Worksheet Tables. From the Figure 2.6, analyst can get the score for Group A (Trunk, Neck and Legs) postures and the Group B (Upper Arms, Lower Arms, and Wrists) postures for left and right hand. Score A is the sum of the Table A score and the Load / Force score. Score B is the sum of the Table B score and the Coupling score for each hand. Score C is read from Table C, by entering it with the Score A and the Score B. The REBA score is the sum of the Score C and the Activity score. The degree of risk is found in the REBA Decision table.

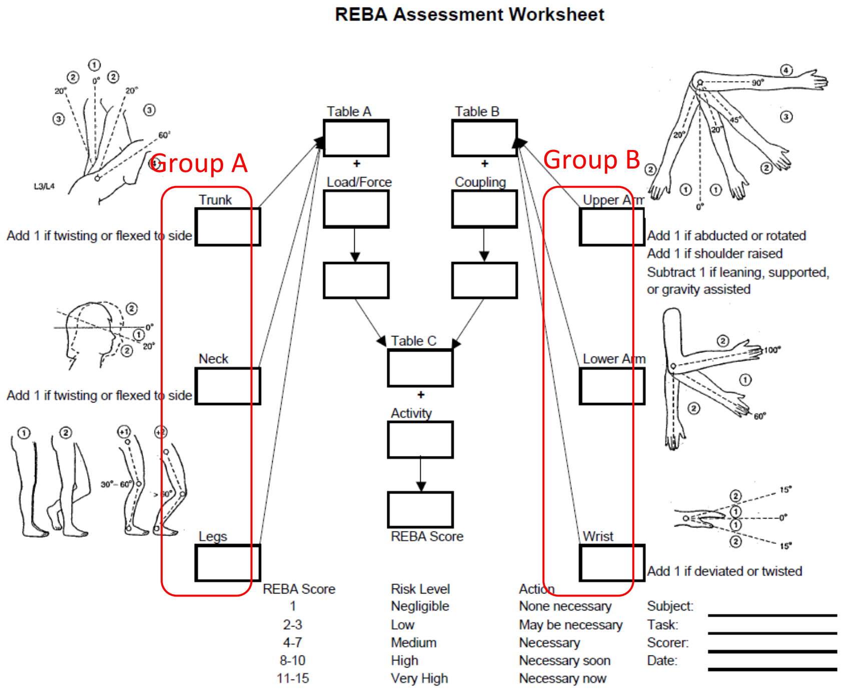

Figure 2.6: REBA Assessment Worksheet

2.8 Strain Index (SI)

The Strain Index is a tool used to evaluate a job's level of risk for developing a disorder of the hand, wrist, forearm, or elbow. This tool is used to evaluate six task variables like intensity of exertion, duration of exertion, exertions per minute, hand/wrist posture, speed of work, and duration of task per day. The sum of the six task variable multipliers produces a number called the strain Index score. In Figure 2.7, the score is used to identify the level of task risk. This tool is fully described by Moore, J. S. and Garg, A., 1995.

Risk Factor	Rating Criterion	Observation	Multiplier	Left	Right
Intensity of Exertion (Borg Scale)	Light	Barely noticeable or relaxed effort [0-2]	1		
	Somewhat Hard	Noticeable or definate effort [3]	3		
	Hard	Obvious effort; unchanged expression [4-5]	6		
	Very Hard	Substantial effort; changed expression [6-7]	9		
	Near Maximal	Uses shoulder or trunk for force [8-10]	13		
Duration of Exertion (% of Cycle)	< 10%		0.5		
	10-29%		1.0		
	30-49%		1.5		
	50-79%		2.0		
	>80%		3.0		
Efforts per Minute If duration of exertion is 100%, then Efforts/Minute multiplier should be set to 3.0	< 4		0.5		
	4-8		1.0		
	9-14		1.5		
	15-19		2.0		
	≥ 20[1]		3.0		
Hand/Wrist Posture	Very Good	Perfectly neutral	1.0		
	Good	Near neutral	1.0		
	Fair	Non-neutral	1.5		
	Bad	Marked deviation	2.0		
	Very Bad	Near extreme	3.0		
Speed of Work	Very Slow	Extremely relaxed pace	1.0		
	Slow	Taking one's own time	1.0		
	Fair	Normal speed of motion	1.0		
	Fast	Rushed, but able to keep up	1.5		
	Very Fast	Rushed and barely/unable to keep up	2.0		
Duration of Task per Day (Hours)	< 1		0.25		
	1 < 2		0.50		
	2 < 4		0.75		
	4 ≤ 8		1.00		
	> 8		1.50		
Results: Find the product of the six multipliers to obtain the SI score		SI ≤ 3	Job is probably safe		
		3 < SI < 7	Job may place individual at increased risk for distal upper extremity disorders		
		7 ≤ SI	Job is probably hazardous		

Figure 2.7: SI Assessment Worksheet

2.9 Predetermined Time Techniques

A predetermined time system include a set of time data and a systematic procedure which analyses and subdivides any manual or human task into motions, body movements, or other elements of human performance, and assigns to each the appropriate time value. Predetermined time systems can be classified according to accuracy level, time required for application, and the extent of method description. It is designed for general use and to most industrial operations. The first predetermined time system was developed by A.B. Segur. Segur called it Methods-Time-Analysis (MTA) (Segur, 1956).

2.10 Methods-Time Measurement (MTM)

Methods-Time Measurement (MTM) can be defined as a procedure to analysis manual operation or method into the most basic motions that required, and assign it to a predetermined time standard. The basic MTM system is MTM-1, it is the most detailed system in MTM family. Motion are broken into 10 categories in MTM-1

1. Reach
2. Move
3. Turn
4. Apply Pressure
5. Grasp
6. Position
7. Release
8. Disengage
9. Body motions
10. Eye motions

Every category has its own predetermined time table. The Unit to measure the MTM is using TMU (Time Measurement Units).

1 TMU = 0.00060minutes = 0.036second or conversely

1hour = 100,000 TMU.

The most accurate predetermined time system is MTM-1, but it requires longer time for analysis, so MTM-2 and MTM-3 is developed. MTM-2 was developed by combine the basic motion in MTM-1. MTM-2 is the best for work that is not highly repetitive and for elements that more than one minute long. There are 9 categories and their symbols in MTM-2:-

Motion (symbol)

1. Get (G)
2. Put (P)
3. Apply Pressure (A)
4. Re-grasp (R)
5. Eye Action (E)
6. Crank (C)
7. Step (S)
8. Foot motion (F)
9. Bend and Arise (B)

2.11 Maynard Operation Sequence Technique (MOST)

MOST is a work measurement technique developed by H.B. Maynard and Company, Inc. in United State (1974). However, MOST has been already introduced into wide varieties of industries in EU, US, and Asia. MOST is a work measurement system that can be easily implemented and practically maintained.
*MOST is a registered trademark of H. B. Maynard and Company, Inc.

User-friendly and easy to learn, MOST has been accepted by countless industries as one of the most efficient work measurement techniques available. Below are advantages of the MOST.

1. Reduces the costs and paperwork and improves productivity.
2. Streamlines operations and quickly identifies inefficient methods.
3. Provides consistent standards and accuracy to within ± 5% with a 95% confidence level.
4. Can be applied to any method-defined manual work.
5. Reduces the time required for data development and standard setting.
6. Is easy to learn and use; even non-Industrial Engineers require little training.
7. Can be applied largely from memory.

There are three sequences in MOST, the general move sequence, the controlled move sequence, and the tool use sequence. In the study of ergonomics in Re-design Workplace Area, the analysis is more focus in manual works of the workers, and manual work is not always performed with hand alone. The use of tools can provide worker can do more jobs compare with bore hand. So, the sequence that can implement in the study is the tool use sequence.

The Tool Use Sequence Model

The five sub-activity phases just listed form the basis for the activity sequence describing the handling and use of hand tools.

Get Tool or object	Put tool or object in place	Use tool	Put tool or object aside	Return operator
A B G	**A B P**		**A B P**	**A**

Where A = Action distance

B = Body motion

G = Gain control

P = Placement

* The blank space in the sequence "Use Tool" is provided with another parameter, which that showed below:-

where:		
	F = Fasten	L = Loosen
	C = Cut	S = Surface treat
	M = Measure	R = Record
	T = Think	

2.12 Ergonomics implement for standing work

Stationary standing is one of postures that used by workers when performing their job duties. Standing work when compared to sitting work, standing work is recommended to do the work when the task cannot be performed with the employees keeping their arms comfortably at their sides. Appropriate standing working postures is use for assembling, testing, or repairing larger products (i.e., greater than 6 inches high).

According to research by Whistance, Adams, van Geems & Bridger (1995), individuals required to stand for prolonged periods adopt asymmetrical standing attitudes four times more often than symmetrical attitudes. Shifting the weight from foot to foot provides an important relief mechanism. Worker will tend to stand with one foot forward, this will increase the stability and also reduce twisting stress when worker turns to the side opposite of the forward foot.

Foot rest is one of the recommendations for standing workstation. The use of a footrest reduces intravertebral disc stress by preventing excessive lordosis (Whistance, Adams, van Geems & Bridger, 1995). According to a study by Rys and Konz (1994), subjects were allowed to stand with no footrest or stand and use one of three different footrests: a flat platform, 15-degree angled platform, or a 50 mm bar. They used the footrest options significantly more than standing without a footrest. They used the bar significantly less than the other two footrest options. The bar was used 59 percent of the time, and the other two platforms were used approximately 80 percent of the time. Subjects switched their foot from the floor to one of the footrests once every 90 seconds.

2.13 Principles of ergonomics

Table 2.1 explains the principles of ergonomics. There are ten principles and its descriptions.

Table 2.1: Principles of ergonomics

Principle ergonomics	**Descriptions**
1. Work in neutral postures	Worker's posture provides a good starting point for evaluating the tasks that you do. The best positions in which to work are those that keep the body in neutral.
2. Reduce excessive force	Excessive force on your joints can create a potential for fatigue and injury.
3. Keep Everything in easy reach	This is the semi-circle that your arms make as you reach out. Things that you use frequently should ideally be within the reach envelope of your full arm. Things that you use extremely frequently should be within the reach envelope.
4. Work at proper heights	most work should be done at about elbow height, whether sitting or standing.
5. Reduce excessive motions	reduce manual repetitions is to use power tools whenever possible.
6. Minimize fatigue and static load	Having a stand for a long time will create a static load on your leg and feet, having a footrest can permit you to reposition your legs and easily to stand.
7. Minimize pressure points	When long period stand statically on hard surface, your heels and feet can begin to hurt and your whole legs can begin to tire, the better way is using anti-fatigue matting.
8. Provide clearance	Work areas need to be set up so that you have sufficient room for your head, your knees, and your feet.
9. Move, exercise, and stretch	To be healthy the human body needs to be exercised and stretched.
10. Maintain a comfortable environment	This principle is more or less a catch-all that can mean different things depending upon the nature of the types of operations that you do.

2.14 Ergonomic Investments (Case Study)

A plant-level exploratory analysis by Tony Brace and Anthony Veltri (2009)

Background

Concerned about the risk of musculoskeletal injuries to line-level employees, plant management arranged for a plant walk-through in order to discuss the manufacturing processes and tasks that may be lead to musculoskeletal risks and disorders. This walk-through is to observe the production process and identify specific tasks that may present exposures to musculoskeletal risk factors.

Methodology

The methodology used to conduct this plant-level exploratory analysis is consisted three phase:-

Phase 1: Perform Up-Front Analysis

- Conduct plant walkthrough
- Secure institutional review board approval.
- Obtain operating performance data.
- Videotape task.

Phase 2: Determine Existing Process Risk & Operational Impact (Task Efficiency)

- Assess existing level of musculoskeletal risk.
  - ➢ Functional task analysis.
  - ➢ Conventional ergonomic analysis tools.
    - ❖ Rapid Upper Limb Assessment (RULA)
    - ❖ ACGIH® TLV® for Hand Activity (HAL)
    - ❖ Moore/Garg Strain Index (SI)
- Assess existing operational impact.
  - ➢ Engineering work measurement tool

- BasicMOST.

Phase 3: Estimate Proposed Solution Risk & Operational Impact (Task Efficiency)

- Estimate proposed solution level of musculoskeletal risk.
  - Functional task analysis.
  - Conventional ergonomic analysis tools.
    - RULA
    - HAL
    - Moore/Garg Strain Index (SI)
- Estimate proposed solution operational impact.
  - Engineering work measurement tool
    - BasicMOST.

2.15 Recommendation Working Postures

The meaning of recommended working posture was describes body positions that are neutral and comfortable when performing tasks. Postures other than which is recommended will generally waste energy and motion as well as potentially raise the musculoskeletal risks. Change position frequently and stretch between tasks can help improves the blood circulation and reduced fatigue. Figure 2.8 show the working postures recommended by Department of Labor Occupational Safety and Health Administration

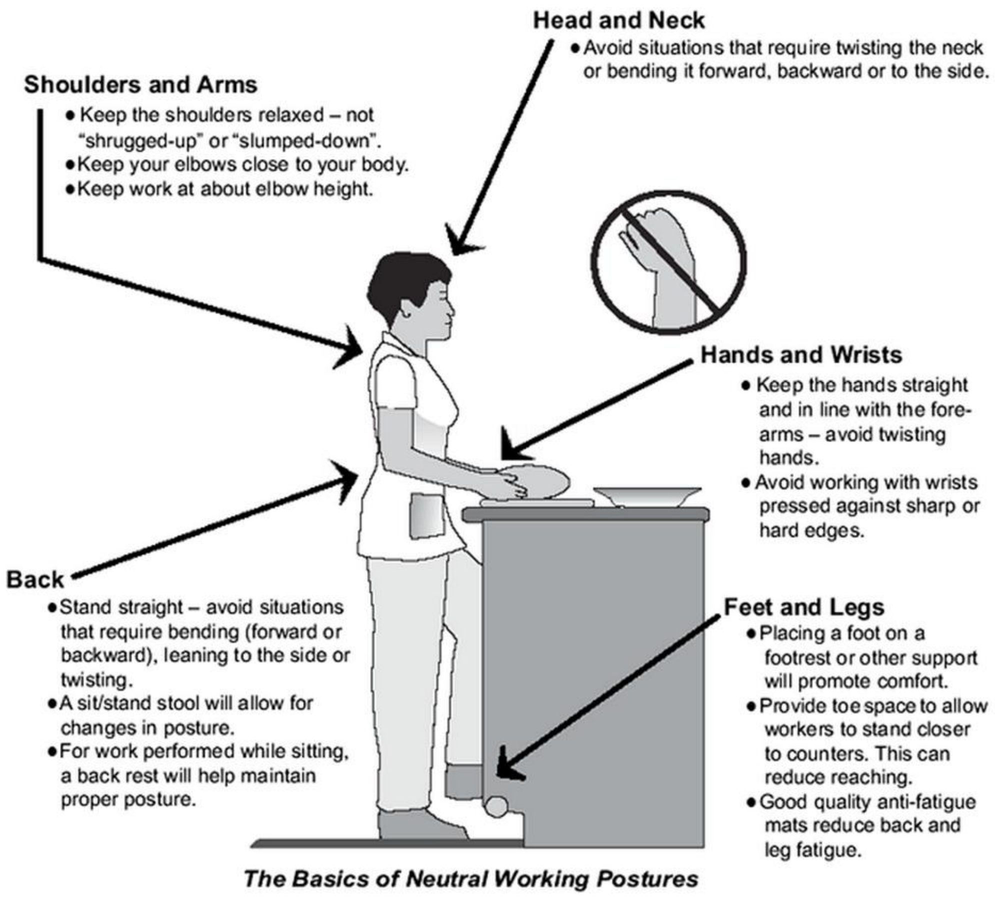

Figure 2.8: Recommended Working Postures

Source: U.S. Department of Labor Occupational Safety and Health Administration, 2004

CHAPTER 3

METHODOLOGY

3.1 Introduction

First of all, the most important concern in this project is to improve productivity through a new workplace area layout with ergonomics features. There are two main parts will be determined in this methodology, Process Musculoskeletal Risk and Operational Impact (Productivity). The methodology used to conduct this project are divided into three phase. Phase one is to perform up-front analysis, phase two is to determine the existing working process risk and operational impact, phase three is to estimate proposed working process risk and operational impact. Re-design workplace area part will be does before start phase three. Finally, the authors will compare the performance of the current process and proposed process.

Flow of executing the project and detail will be explained later.

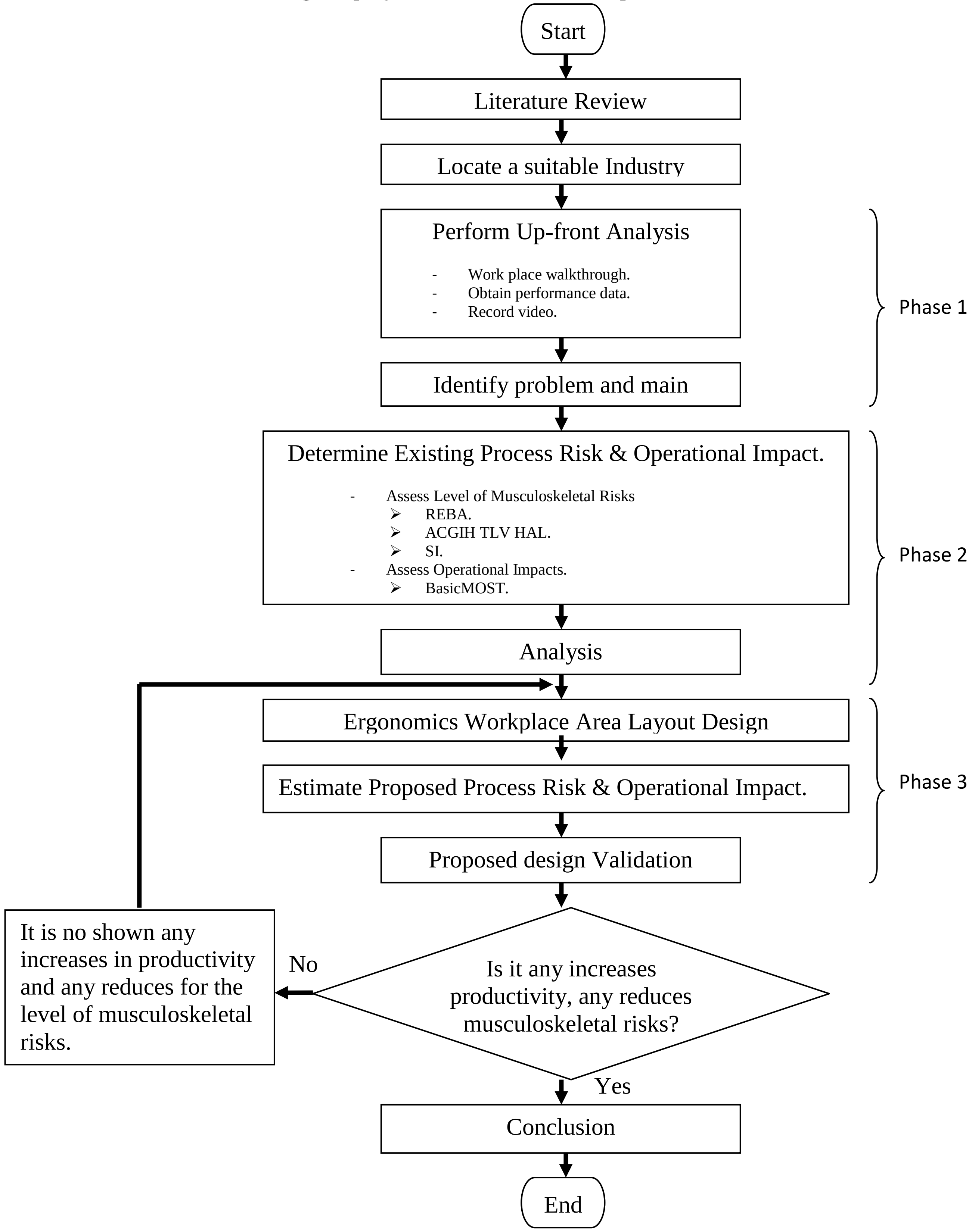

Figure 3.1: Methodology flow chart

3.2 Literature Review

In the literature review, the information needed is used to conduct methodology for this project, the conventional ergonomics analysis tools learned from literature review is used to assess the level of musculoskeletal risks and discomforts in this project, like REBA, HAL, and Strain Index. To determine the operational impact, the predetermined time technique has involved, in this case, MOST is used to estimate the operational impact. For the workplace design part, the knowledge and technology needed is not enough if only getting from previous literature review, updated information and technology needed to design a workplace area layout with updated ergonomics features, so reading more books, browsing the internet, having discussion with supervisor can helped a lot in new workplace area layout design.

3.3 Phase One

Phase one involved a walk-through of the company to discuss and investigation the various manual work processes and tasks that may linked to musculoskeletal risks and discomfort, and also the operating performance details and data about manual works of the workers like number of hours worked per day, number of product manufactured per day, possibility exposures to musculoskeletal risks and discomforts. The company visitation date will be discuss with owner, and the confirmed to do visitation was 28, 29 march, and 4, 5 April. The investigation will last at two weeks or until data needed be collected. In addition, a working process video has to record during data collection.

3.4 Phase Two

Phase 2 is to determine the musculoskeletal risk of existing working process and operational impact. Video recording was applied in this phase, study the various working process, and operational tasks and subtasks in video to determine the level of musculoskeletal risks. The ergonomics analysis tools used is Rapid Entire Body Assessment (REBA), and Strain Index (SI) showed in Figure 3.2 & 3.3.

Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) Date: / /

Task	Analyst

Group A Posture/Range	Score	Total	Group B Posture/Range	Score	Total: Left and Right	
Trunk			**Upper Arms** (Shoulders)		L	R
Upright	1	If back is twisted or tilted to side: +1	Flexion: 0-20° Extension: 0-20°	1	Arm Abducted / Rotated: +1 Shoulder Raised: +1 Arm Supported: -1	
Flexion: 0-20° Extension: 0-20°	2		Flexion: 20-45° Extension: >20°	2		
Flexion: 20-60° Extension: >20°	3		Flexion: 45-90°	3		
Flexion: >60°	4		Flexion: >90°	4		
Neck			**Lower Arms** (Elbows)		L	R
Flexion: 0-20°	1	If neck is twisted or tilted to side: +1	Flexion: 60-100°	1	No Adjustments	
Flexion: >20° Extension: >20°	2		Flexion: <60° Flexion: >100°	2		
Legs			**Wrists**		L	R
Bilateral Wt Bearing; Walk; Sit	1	Knee(s) Flexion 30-60°: +1 Knee(s) Flexion >60°: +2	Flexion: 0-15° Extension: 0-15°	1	Wrist Deviated / Twisted: +1	
Unilateral Wt Bearing; Unstable	2		Flexion: >15° Extension: >15°	2		
Score from Table A			**Score from Table B**		L	R
Load / Force			**Coupling**		L	R
< 5 kg < 11 lb	0	Shock or Rapid Buildup: +1	Good	0	No Adjustments	
5 - 10 kg 11 - 22 lb	1		Fair	1		
> 10 kg > 22 lb	2		Poor	2		
Score A [Table A + Load/Force Score]			Unacceptable	3	Left	Right
Activity			**Score B** [Table B + Coupling Score]		L	R
One or more body parts are static for longer than 1 minute		+1	**Score C** (from Table C)		L	R
Repeat small range motions, more than 4 per minute		+1	**Activity Score**		L	R
Rapid large changes in posture or unstable base		+1	**REBA Score** [Score C + Activity Score]		L	R

Figure 3.2: Rapid Entire Body Assessment Worksheet

Source: REBA V1.1 5/4/01 ©2001 Thomas E. Bernard

Strain Index (SI)

Risk Factor	Rating Criterion	Observation	Multiplier	Left	Right
Intensity of Exertion (Borg Scale)	Light	Barely noticeable or relaxed effort [0-2]	1		
	Somewhat Hard	Noticeable or definate effort [3]	3		
	Hard	Obvious effort; unchanged expression [4-5]	6		
	Very Hard	Substantial effort; changed expression [6-7]	9		
	Near Maximal	Uses shoulder or trunk for force [8-10]	13		
Duration of Exertion (% of Cycle)	< 10%		0.5		
	10-29%		1.0		
	30-49%		1.5		
	50-79%		2.0		
	>80%		3.0		
Efforts per Minute If duration of exertion is 100%, then Efforts/Minute multiplier should be set to 3.0	< 4		0.5		
	4-8		1.0		
	9-14		1.5		
	15-19		2.0		
	≥ 20[1]		3.0		
Hand/Wrist Posture	Very Good	Perfectly neutral	1.0		
	Good	Near neutral	1.0		
	Fair	Non-neutral	1.5		
	Bad	Marked deviation	2.0		
	Very Bad	Near extreme	3.0		
Speed of Work	Very Slow	Extremely relaxed pace	1.0		
	Slow	Taking one's own time	1.0		
	Fair	Normal speed of motion	1.0		
	Fast	Rushed, but able to keep up	1.5		
	Very Fast	Rushed and barely/unable to keep up	2.0		
Duration of Task per Day (Hours)	< 1		0.25		
	1 < 2		0.50		
	2 < 4		0.75		
	4 ≤ 8		1.00		
	> 8		1.50		
Results: Find the product of the six multipliers to obtain the SI score		SI ≤ 3	Job is probably safe		
		3 < SI < 7	Job may place individual at increased risk for distal upper extremity disorders		
		7 ≤ SI	Job is probably hazardous		

Figure 3.3: SI Assessment Worksheet

Source: Strain Index Scoring Sheet ©12/06 The Ergonomics Center of North Carolina.

To determine the operational impact, a predetermined time technique called Maynard Operating Sequence Technique (BasicMOST) is used in this project. Figure 3.4 show a MOST assessment calculation form

<table>
<tr><td colspan="3" rowspan="2">MOST - Calculation</td><td colspan="2">Code:</td></tr>
<tr><td colspan="2">Date:</td></tr>
<tr><td colspan="3" rowspan="2">Area:</td><td colspan="2">Sign:</td></tr>
<tr><td colspan="2">Page: /</td></tr>
<tr><td colspan="5">Activity:</td></tr>
<tr><td colspan="5">Conditions:</td></tr>
<tr><td>No.</td><td>Method</td><td>Sequence Model</td><td>Fr.</td><td>TMU</td></tr>
<tr><td>1</td><td>Describe activity 1</td><td>Ax Bx Gx Ax Bx Px Ax</td><td></td><td></td></tr>
<tr><td>2</td><td>Describe activity 2</td><td>Ax Bx Gx Ax Bx Px Ax</td><td></td><td></td></tr>
<tr><td>3</td><td>Describe activity 3</td><td>Ax Bx Gx Mx Xx Ix Ax</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Ax Bx Gx Ax Bx Px _ Ax Bx Px Ax</td><td></td><td></td></tr>
<tr><td colspan="2">TIME =</td><td>minutes (min.)</td><td colspan="2"></td></tr>
</table>

Figure 3.4: MOST assessment calculation

Source: H.B. Maynard and Company, Inc, Maynard Operation Sequence Technique

Figure 3.5 shows a functional task analysis, to find the estimation of cycle time. The cycle movement was recorded by camera for further analysis.

<table>
<tr><td rowspan="2">Task</td><td rowspan="2">Subtask</td><td colspan="2">Labor time</td></tr>
<tr><td>TMU</td><td>Minutes</td></tr>
<tr><td rowspan="3"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="3"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total Labor time</td><td></td><td></td></tr>
</table>

Figure 3.5: Functional Task Analysis

3.5 Phase Three

Phase three is to estimate the new designed workplace area's performance. Similar methodology in phase three as phase two will be applied to estimate the estimation of working process risk and operational impact such as REBA, SI, and BasicMOST. Before start phases three, a new workplace area was designed according to guidelines on occupational safety and health (For Standing At Work). FIgure 3.6 show the ideal measurements of a workspace envelope.

The basic design principles should be:-

- Avoid tasks which require standing in static posture.
- Provide a chair or a stool for sitting on or standing against.

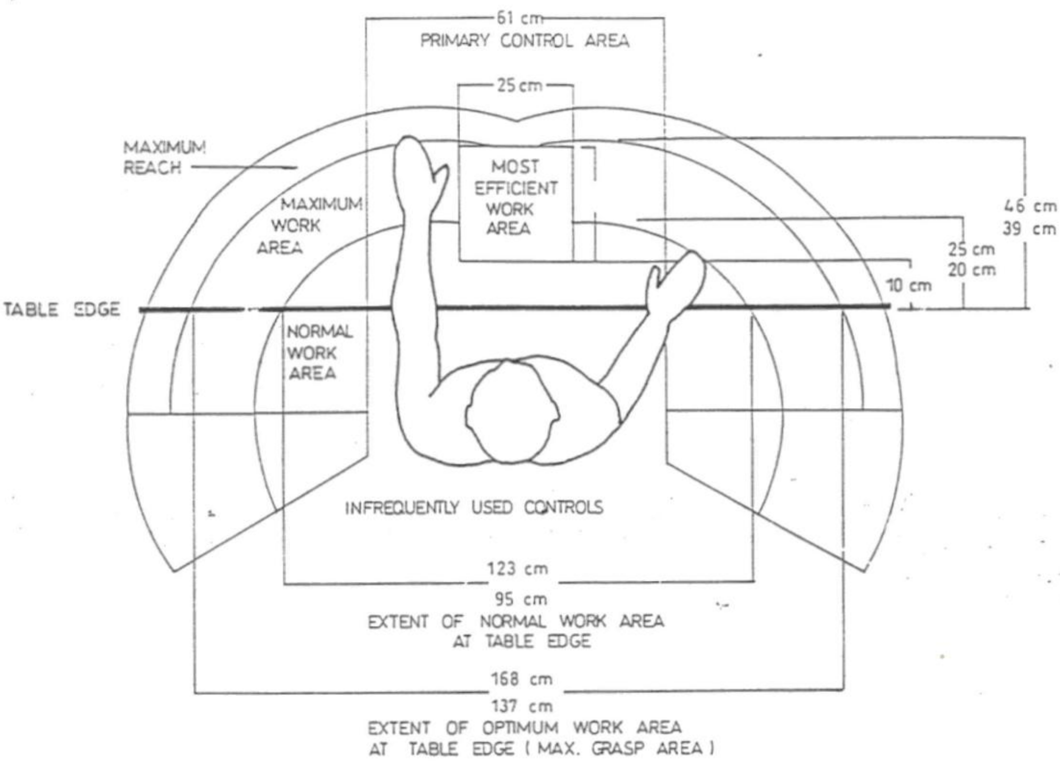

Figure 3.6: The Ideal Measurements of a Workspace Envelope

3.6 Proposed design Validation

The validation has to do on proposed design as to validate the musculoskeletal risks and the productivity improvement. The musculoskeletal risks is determined by using the ergonomics analysis tools which similar as in phase two, is Rapid Entire Body Assessment (REBA), and Strain Index (SI). To determine the labor time, Maynard Operating Sequence Technique (BasicMOST) is used in this project. The data comparison will be focus in two parts, musculoskeletal risk of both designs, and productivity improvement. Equation 3.1 & 3.2 use to calculate cycle time improvement and distance moved reduction.

$$Cycle\ time\ improvement = \frac{Exist\ Labor\ time - Proposed\ Labor\ time}{Exist\ Labor\ time} \times 100\% \qquad (3.1)$$

$$Distance\ moved\ reduction = \frac{Exist\ distance - Reduced\ distance}{Exist\ distance\ moved} \times 100\% \qquad (3.2)$$

The collected data will be compared to the existing data and observed any changes in the musculoskeletal risks and productivity improvement as in Table 3.5.

From Figure 3.7, if the result didn’t show any improvement in productivity and reduction in musculoskeletal risks, the proposal of new design will be rejected, and continue to new workplace design. If the result is show improvement in productivity and reduction in musculoskeletal risks, the result is positive means the design is satisfy and successfully, then will proceed to conclusion part.

Category	Existing	Propose
Number of hours worked per day.		
Number of products manufactured		
Labor productivity (Number of products per labor hour)		
Investment costs required		
Functional task analysis (Number of sub tasks involved)		
Musculoskeletal risks	REBA= low/medium/high. SI = safe/ not safe.	REBA= low/medium/high. SI = safe/ not safe.
Labor time/ cycle time (minutes)		
Productivity increase		

Figure 3.7: Data comparison for Existed and proposed

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the up-front analysis and observation obtained from SidmannComposite Sdn Bhd was collected and presented. Level of musculoskeletal risks and labor time in time measurement unit was determined. From the data collected, a new workplace area was designed based on ergonomic knowledge by using SolidWork and fabrication. Several factors have been focused on during data collection. The focus points were,

i) Existing and proposed level of musculoskeletal risks.
ii) Existing and proposed level of labor time.
iii) Cycle time improvement and travel distance reduction.

Basic-Most technique, Rapid Entire Body Assessment and Strain Index was involved to calculate the level of musculoskeletal risks and labor time.

4.2 Existing and proposed level of musculoskeletal risk

From the original workplace area that showed in Figure 4.1 (a) & (b), workers was facing some musculoskeletal risks when doing their job with not suitable table's height. From the figure also show there is no any footrest provided in this company, therefore this discomfort posture can lead to musculoskeletal disorders like back pain. From testimony of worker with one years experience in Sidmann Compostie Sdn. Bhd., there were not many musculoskeletal disorders facing by them by performing this task, However, the workers had complained to height of table is not comfortable to working when doing concentrated job, like engraving mold, mold cleaning.

(a) (b)

Figure 4.1(a) & (b): Workers working postures at Sidmann Composite SDN BHD

4.3 Ergonomics investment that propose to the company

From the testimony and observation concluded from workers, there are two investments can be proposed to the company, a height adjustable table and a ergonomics foot rest.

A height adjustable table designed as showed in Figure 4.2 following guidelines on occupational safety and health (Department of Occupational Safety and Health Ministry of Human Resources) and guideline on working in standing position (Canadian Centre for occupational Health & Safety) was introduced to the company. The height adjustable table can provides workers a suitable height of workplace area for working. For example, a low height table use to do heavy work, a moderate height table to do light work like glue brushing, putting fiberglass mat. High height table can be use to do precision work like engraving mold, mold cleaning. Height adjustable table also suitable for different height workers, workers can adjust different height to fix their working postures. The mode worker’s elbow height in Sidmann Composite was 100cm height, so the dimension of the table design is 65cm-105cm height, 200cm width, and 80cm depth. The adjustable height is 65cm, 75cm, 85cm, 95cm and 105cm counted from 0 from the contact floor.

Figure 4.2: Height Adjustable Table drawn by Solidwork

An ergonomics foot rest as showed in Figure 4.3 (b) was designed and fabricated to reduce the level of musculoskeletal risks of workers. The main function of this ergonomics foot rest is to reduce intravertebral disc stress by preventing excessive lordosis (Whistance, Adams, van Geems & Bridger, 1995). Workers can stand with one foot forward, which increases their stability and also can reduce twisting stress if the person turns to the side opposite of the forward foot. A actual ergonomics foot rest was fabricated to get the testimony from workers. The testimonial from worker was say that not much different compare when no foot rest provided. The reason was workers already be used their ordinarily postures, so after foot rest is provided, they no accustomed to new postures. The benefit of ergonomics foot rest will be felt after a longer period resting on it. The dimension of ergonomics foot rest is 37cm height, 55cm width, 50cm depth. The adjustable height is 15cm, 20cm, and 25cm counted from 0 from the contact floor.

Figure 4.3 (a): Ergonomics footrest drawn by Solidwork

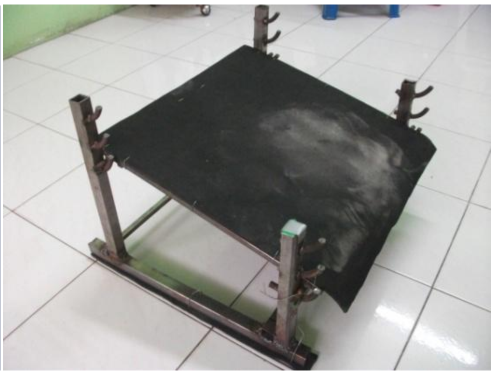

Figure 4.3 (b): Actual Ergonomics footrest

4.4 Result for tools assessing musculoskeletal risk

Table 4.1: REBA and SI assessment result

Task	**REBA SCORE Original**		**REBA SCORE Proposed**	
	Left Hand	**Right Hand**	**Left Hand**	**Right Hand**
Mold brushing	5	5	3	3
	0-1 Negligible			
	2-3 Low			
	4-7 Medium			
	8-10 High			
	11-15 Very high			
Task	**SI SCORE Original**		**SI SCORE Proposed**	
	Left Hand	**Right Hand**	**Left Hand**	**Right Hand**
Mold brushing	3.375	0.375	3.375	0.375
	$SI \leq 3$ Job is probably safe			
	$3 < SI < 7$ Job may place individual at increased risk for distal upper extremity disorders			
	$SI \geq 7$ Job is probably hazardous			

From the result showed in Table 4.1, the level of musculoskeletal risk for REBA show big reduction from medium risk to low risk. Refer from the REBA result get in appendix O and appendix P, the different between REBA score and SI score is the score in “Table A”. After new design was proposed, the score of postures for trunk was reduced from 2 to 1, this was caused by the implement of height adjustable table, worker can adjust the table to fix their posture without bending their trunk. Other than this, the score of postures for neck was reduced from 2 to 1 also, the implement of ergonomics foot rest give support for worker to bending their body forward more easily with support of the foot rest, so they can more relax and prevent the posture that show in Figure 4.1 (a) & (b).

The result in SI remain the same, this is because there was no any new design is proposed to reduce the strain index for workers, due to don’t have any implement to reduce the duration or intensity of exertion of this task.

4.5 Existing and proposed level of cycle time.

From Figure 4.4 (a), the workplace arrangement is arranged according to the practice in Sidmann Composite SDN BHD. The distance between each component is calculated using grid paper that show in Figure 4.4 (a), range of grip is 2 in each. The distance between each component is use to assist Basic-MOST calculation. Basic-MOST technique was used to determine labor time for the analysis. Analysis is made by using video recorded when workers performing task “Mat brushing”. The movement of worker was analysis by using Basic-MOST to determine the labor time.

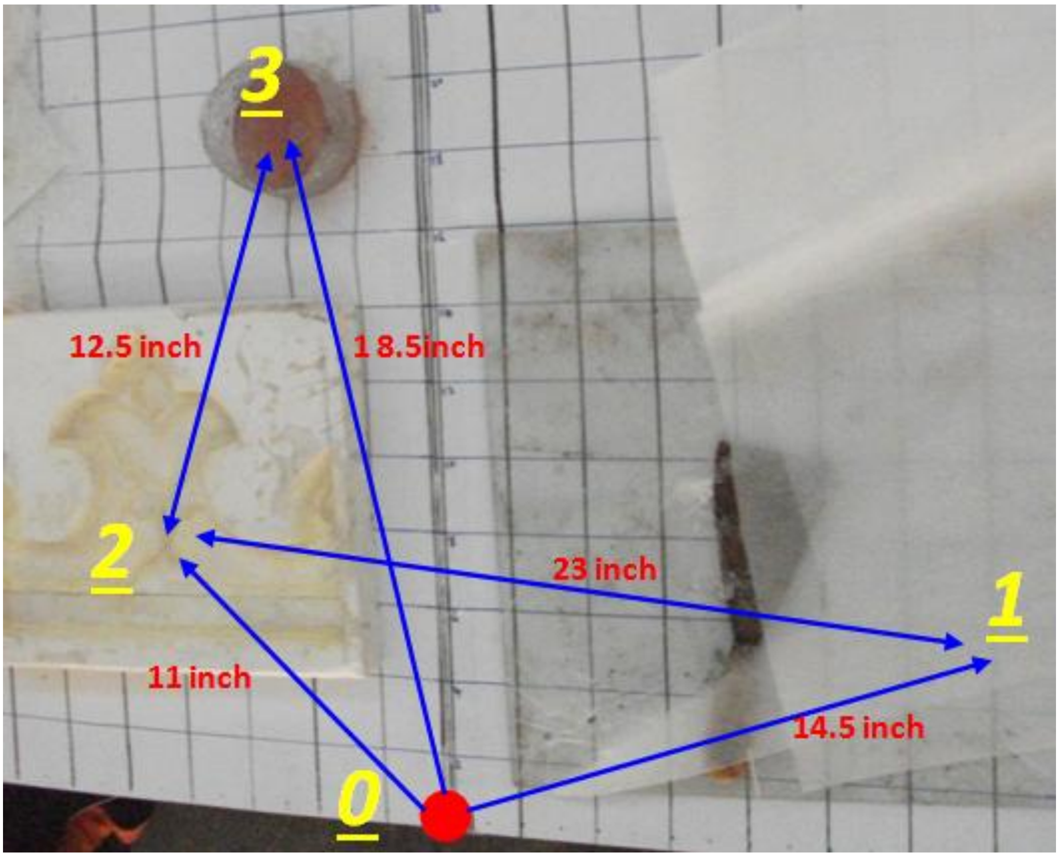

Figure 4.4 (a): Original workplace arrangement in industry

4.6 Work place arrangement improvement

From Figure 4.4 (b), workplace area arrangement is arranged according to the ideal measurements of a workspace envelope in Figure 3.2 as highlighted in guidelines on occupational safety and health (For Standing At Work). All components should be placed inside primary control area. Inside primary control area, mold place in the most efficient work area, and mat, glue, and brush place in normal work area. The distance between 0 and 1 is reduced from 14.5 in to 14 in, the distance between 0 and 2 is reduced from 11 in to 7 in, and the distance between 1 and 2 is reduced from 22 in to 14 in.

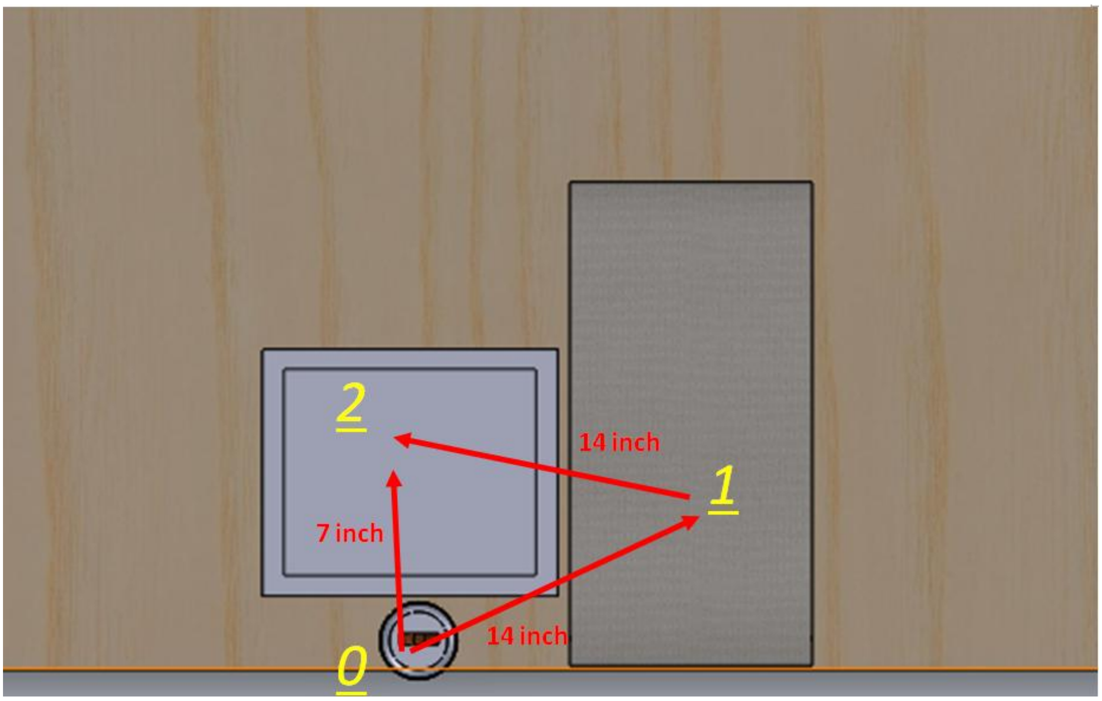

Figure 4.4 (b): Workplace arrangement drawn by Solidwork

4.7 Tool assessing cycle time (Predetermined Time Techniques)

From Table 4.2, tasks are separate into 2 sections, first section is put fiber glass into mold, second section is brushing the glue on fiber glass mat. Each section have it own sub-task as shown in table 4.2. Movements of worker were divided in MTM units like reach, grasp, move, release, and apply pressure. Labor time in TMU unit and distance moved in inch was determined for Original labor time and proposed labor time. The Labor time for original workplace was 255.5 TMU, which equal to 9.2 s, and total distance moved was 66 in. For the proposed workplace, the Labor time was 243.5 TMU, which equal to 8.75 s, and total distance moved was 49 inch.

Table 4.2: MTM assessment result

Task	**Sub-Task**	**Method-time measurement (MTM)**	**Original labor time**		**Proposed labor time**	
			TMU	**Distance (Inch)**	**TMU**	**Distance (Inch)**
1. Put fiber glass into mold	take fiber glass mat	Reach	14.4	14	14.4	14
		Apply Pressure	10.6	-	10.6	-
		Grasp	3.5	-	3.5	-
		Apply Pressure	10.6	-	10.6	-
	put into mold	Move	19.4	22	14.6	14
		Release	2	-	2	-
	Press fiber glass mat	Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
2. Brushing the glue on fiber glass mat	take the brush	Reach	11.5	10	9.3	7
		Grasp	8.7	-	8.7	
	brush the mat	Move	12.2	10	9.3	7
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
		Apply Pressure	10.6	-	10.6	-
	put back the brush	Move	12.2	10	12.2	7
		Release	2	-	2	-
		Total labor time	255.5	66	243.5	49

4.8 Cycle time Improvement and Travel Distance reduction

Refer to Figure 4.5, cycle time for proposed design was slightly lower than original design, it is 4.7% lower than original design. The proposed design only improve in factor workplace arrangement, so the improvement is only made on travel distance, MTM's change involve reach and move. It only minor changes in whole task analysis, so improvement was only slightly changed.

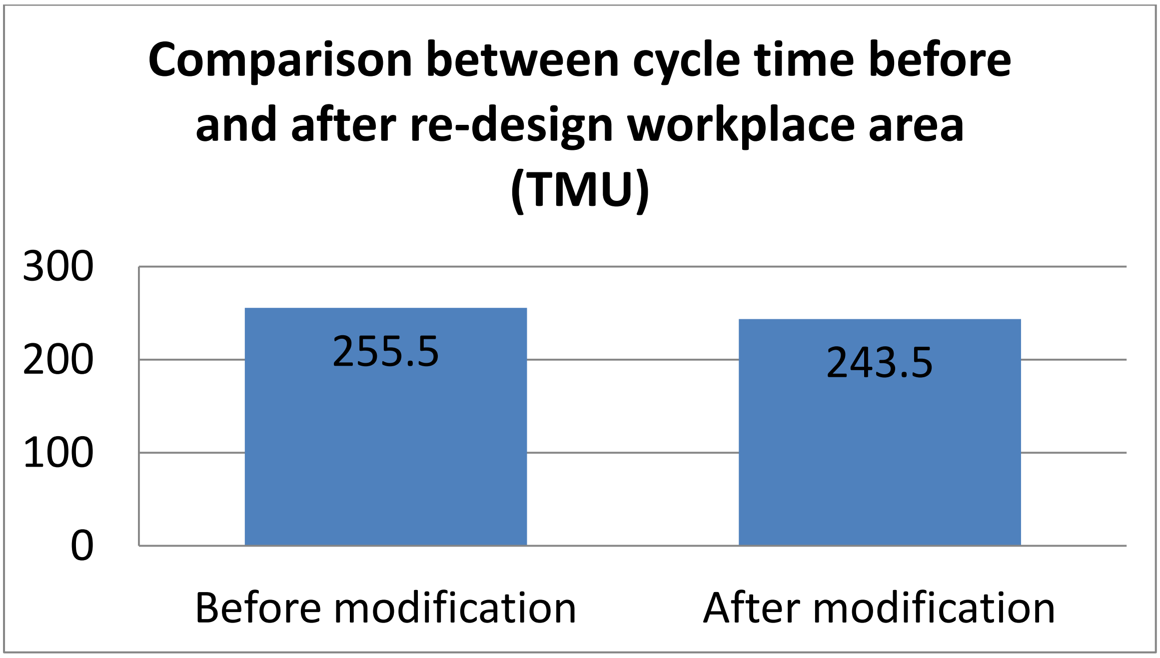

Figure 4.5: Graph of comparison between cycle time before and after re-design workplace area

$$Cycle\ time\ improvement = \frac{255.5 - 243.5}{255.5} \times 100\%$$

$$Cycle\ time\ improvement = 4.7\%$$

Refer to Figure 4.6, travel distance for proposed design was lower than original design, it is 25.8% lower than original design. Compare with Figure 4.5, the percentage of change is much more higher, this is because Figure 4.6 is only focus on the travel distance, it already filter the unused result when worker performing apply pressure and grasp that take in count in graph in Figure 4.5, so the result of improvement can be see more clearly.

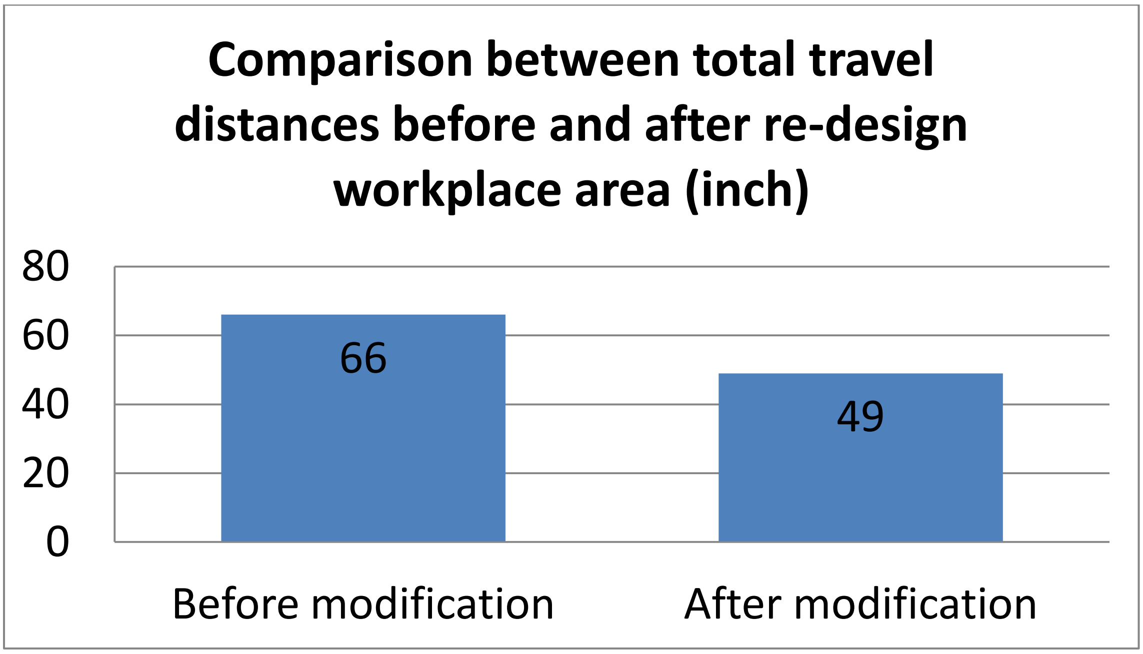

Figure 4.6: Graph of comparison between total travel distance before and after re-design workplace area

$$Travel\ distance\ reduction = \frac{69 - 49}{69} \times 100\%$$

$$Travel\ distance\ reduction = 25.8\%$$

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project was successfully carried out at Sidmann Composite SDN BHD. Two types of ergonomics investment were proposed for the company, height adjustable table and ergonomics footrest. The purpose of these two suggestions is to reduce level of musculoskeletal risks. It was discovered that the level of musculoskeletal risks were successfully improved from medium to low. Apart from that, cycle time was improved by 4.7% and the travel distance was also improved 25.8% after new work place arrangement was implemented. For the conclusion, re-design workplace area with ergonomics implement has slightly improved the productivity of the process mat brushing. A summary of Task analysis was concluded in table 5.1.

Table 5.1: Summary of task analysis

Category	Original workplace design	Proposed workplace design
Ergonomic Investment	-	1) Height Adjustable Table 2) Ergonomic Footrest 3) Working Area Re-arrangement
Labor Time Calculated (Second)	9.2	8.8
Distance Moved (Inch)	66	49
Musculoskeletal Risks	REBA= medium SI = safe	REBA= low SI = safe
Cycle time improvement (%)	-	4.7
Travel distance Reduced (%)	-	25.8
Worker Testimony	1) Table not suitable for precision works. 2) No other big problem.	1) Happily if having height adjustable table. 2) Footrest no feeling any big different.

5.2 Recommendations

Although the project objectives were successfully achieved, but it’s still has several ways could be done to improve result’s accuracy. Several recommendations can be considered for the good of the future.

The costs of acquisition, training and the needed time for undertake assessment and processing the result will vary for different method, this project was having a limited time to carry out the assessment, therefore the analysis tools used was straightforward and quick to use. One of the recommendations is using alternative observation techniques to access the level of musculoskeletal risk. Compare to REBA, technique like OCRA or QEC are also can be use for access the level of musculoskeletal risk, and they also have more factor can be accessed like duration of work and vibration.

For further study that more focus on musculoskeletal risk, a more complex technique that involved video analysis is also a good ways to access the level of musculoskeletal risks. The function of Tri-axial video-based observational method for quantification of exposure can be computerize to get the estimation of repetitiveness, body postures, force and velocity by using dedicated software.

Due to lack of equipment and techniques, this project is only focus on one task in whole process to do the cycle time analysis by using BasicMOST. the analysis having low accuracy and efficiency. Using computer-aided technique which can more clearly divided workers movement by using video analysis to do full analysis for whole process is suggested to get the more accurate result.

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APPENDIX A

Table 1. MTM-1 Reach

Distance Moved in Inches	Time TMU				Hand in Motion	
	A	B	C or D	E	A	B
3/4 or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	5.9	3.8	3.5	2.7
3	5.3	5.3	7.3	5.3	4.5	3.6
4	6.1	6.4	8.4	6.8	4.9	4.3
5	6.5	7.8	9.4	7.4	5.3	5.0
6	7.0	8.6	10.1	8.0	5.7	5.7
7	7.4	9.3	10.8	8.7	6.1	6.5
8	7.9	10.1	11.5	9.3	6.5	7.2
9	8.3	10.8	12.2	9.9	6.9	7.9
10	8.7	11.5	12.9	10.5	7.3	8.6
12	9.6	12.9	14.2	11.8	8.1	10.1
14	10.5	14.4	15.6	13.0	8.9	11.5
16	11.4	15.8	17.0	14.2	9.7	12.9
18	12.3	17.2	18.4	15.5	10.5	14.4
20	13.1	18.6	19.8	16.7	11.3	15.8
22	14.0	20.1	21.2	18.0	12.1	17.3
24	14.9	21.5	22.5	19.2	12.9	18.8
26	15.8	22.9	23.9	20.4	13.7	20.2
28	16.7	24.4	25.3	21.7	14.5	21.7
30	17.5	25.8	26.7	22.9	15.3	23.2
Additional per inch over 30 inches	0.4	0.7	0.7	0.6		

APPENDIX B

Table 2. MTM-1 Move

Distance moved in Inches	Time TMU				Wt. Allowance		
	A	B	C	Hand In Motion B	Wt. (lb). Up to	Dynamic Factor	Static Constant TMU
¾OR LESS	2.0	2.0	2.0	1.7	2.5	1.00	0
1	2.5	2.9	3.4	2.3			
2	3.6	4.6	5.2	2.9	7.5	1.06	2.2
3	4.9	5.7	6.7	3.6			
4	6.1	6.9	8.0	4.3	12.5	1.11	3.9
5	7.3	8.0	9.2	5.0			
6	8.1	8.9	10.3	5.7	17.5	1.17	5.6
7	8.9	9.7	11.1	6.5			
8	9.7	10.6	11.8	7.2	22.5	1.22	7.4
9	10.5	11.5	12.7	7.9			
10	11.3	12.2	13.5	8.6	27.5	1.28	9.1
12	12.9	13.4	15.2	10.0			
14	14.4	14.6	16.9	11.4	32.5	1.33	10.8
16	16.0	15.8	18.7	12.8			
18	17.6	17.0	20.4	14.2	37.5	1.39	12.5
20	19.2	18.2	22.1	15.6			
22	20.8	19.4	23.8	17.0	42.5	1.44	14.3
24	22.4	20.6	25.5	18.4			
26	24.0	21.8	27.3	19.8	47.5	1.50	16.0
28	25.5	23.1	29.0	21.2			
30	27.1	24.3	30.7	22.7			
Additional	0.8	0.6	0.85		TMU per inch over 30 inches		

APPENDIX C

Table 3. MTM-1 Turn

Weight	Time TMU for Degrees Turned										
	30	45	60	75	90	105	120	135	150	165	180
Small 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium 2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large 10 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

APPENDIX D

Table 4. MTM-1 Apply Pressure (Barnes, 1980), (Konz, 1995)

Full Cycle			Components		
Symbol	TMU	Description	Symbol	TMU	Description
APA	10.6	AF+DM+RLF	AF	3.4	Apply Force
			DM	4.2	Dwell, Minimum
APB	16.2	APA+G2			
			RLF	3.0	Release Force

APPENDIX E

Table 5. MTM-1 Grasp

Type of Grasp	Case	Time TMU	Description	
Pick-UP	1A	2.0	Any size object by itself, easily grasped.	
	1B	3.5	Object very small or lying close against a flat surface.	
	1C1	7.3	Diameter Larger than ½"	Interference with Grasp on bottom and one side of nearly cylindrical object.
	1C2	8.7	Diameter 1/4" to 1/2"	
	1C3	10.8	Diameter Less than 1/4"	
Regrasp	2	5.6	Change grasp without relinquishing control.	
Transfer	3	5.6	Control transferred from one hand to the other.	
Select	4A	7.3	Larger than 1 x1 x1	Object jumbled with other objects so that search and select occur.
	4B	9.1	1/4 x1/4 x1/8 to 1 x1 x1	
	4C	12.9	Smaller than 1/4 x1/4 x1/8	
Contact	5	0	Contact, Sliding, or Hook Grasp.	

APPENDIX F

Table 6. MTM-1 Position

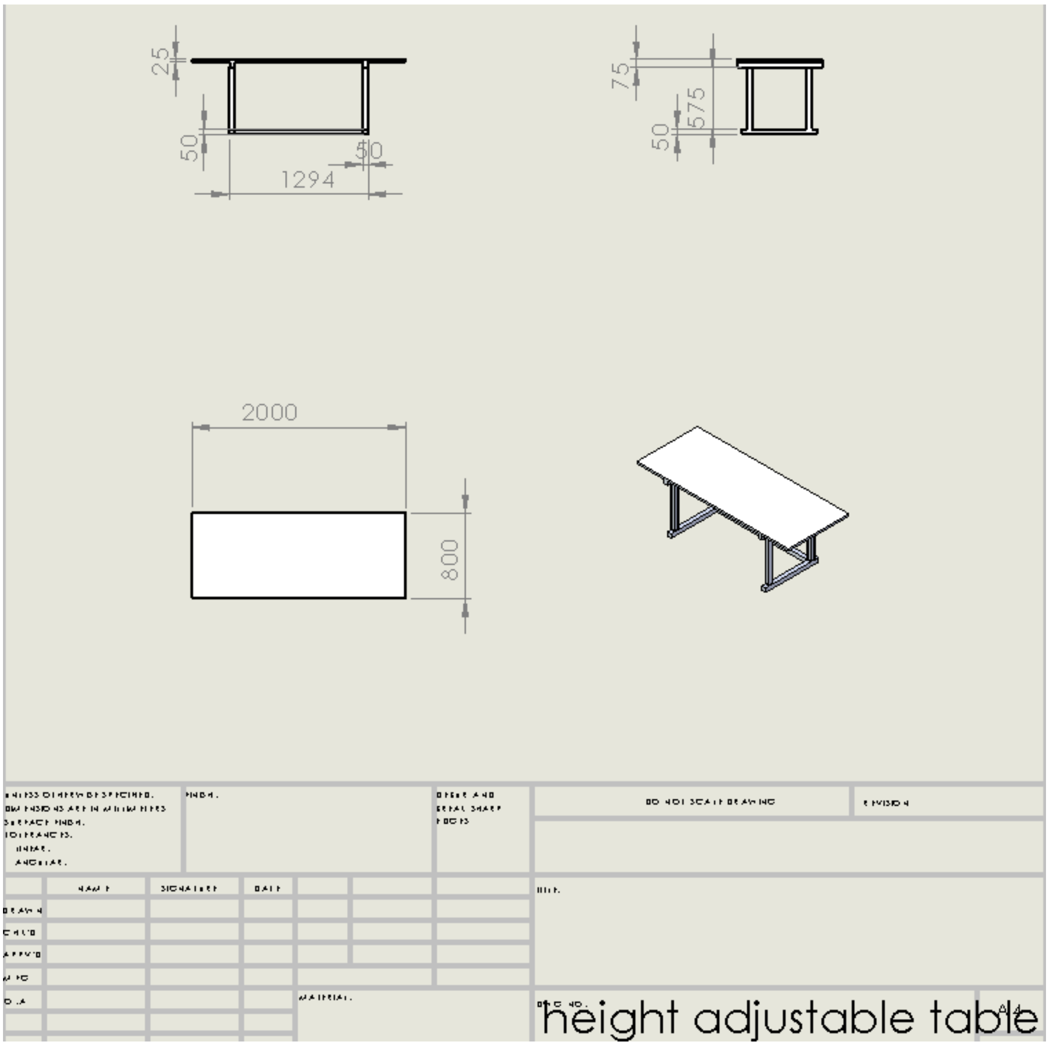
Class of Fit	Symmetry	Easy to Handle	Difficult to Handle
1 Loose	S	5.6	11.2
	SS	9.1	14.7
	NS	10.4	16.0
2 Close	S	16.2	21.8
	SS	19.7	25.3
	NS	21.0	26.6
3 Exact	S	43.0	48.6
	SS	46.5	52.1
	NS	47.8	53.4
Supplementary Rule for Surface Alignment			
P1SE per alignment: >1/16 1/4		P2SE per alignment: 1/16	

APPENDIX G

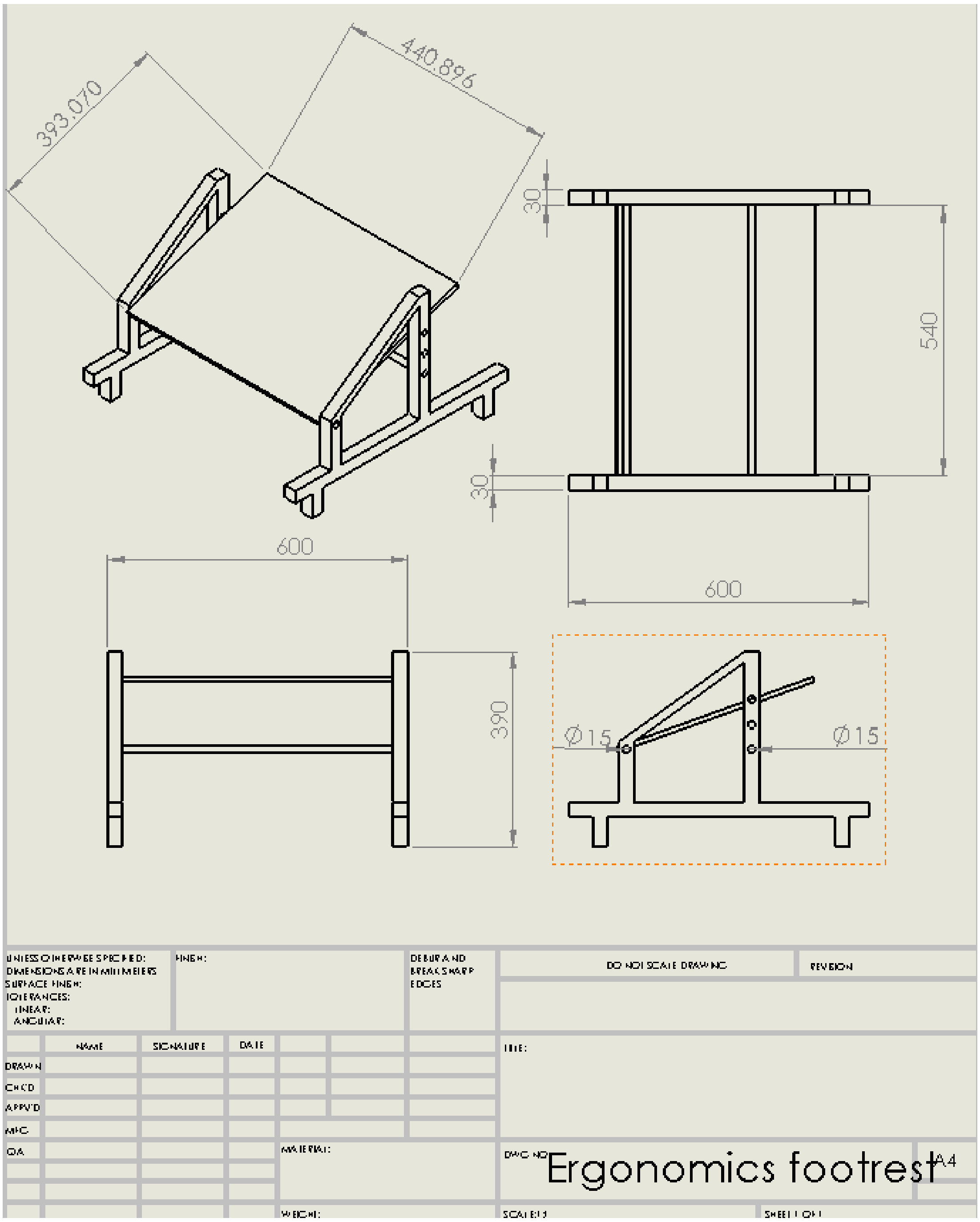
Table 7. MTM-1 Release

Case	Time TMU	Description
1	2.0	Normal release performed by opening fingers as independent motion
2	0	Contact Release

APPENDIX H



APPENDIX I


393.070
440.896
30
540
30
600
600
390
Ø15
Ø15
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
TITLE:
DWG NO.
Ergonomics footrest
A4
WEIGHT:
SCALE:1:5
SHEET 1 OF 1

APPENDIX J

MTM assessment result for analysis No. 1

Number	type	class	distance	TMU		
1	Reach	B	20	18.6		
2	Grasp	1B		3.5		
3	Move	A	5	7.3		
4	Apply Pressure	APA		10.6		
5	Move	B	20	18.2		
6	Apply Pressure	APA		10.6		
7	Move	B	6	8.9		
8	Move	B	10	12.2		
9	Move	B	16	15.8		
10	Grasp	Transfer		5.6		
11	Release	1		2		
12	Apply Pressure	APA		10.6		
13	Apply Pressure	APA		10.6		
14	Apply Pressure	APA		10.6		
15	Reach	B	16	15.8		
16	Grasp	1B		3.5		
17	Reach	B	6	8.6		
18	Grasp	1B		3.5		
19	Move	B	9	6.9		
20	Move	B	20	18.2		
21	Move	B	6	8.6		
22	Turn		90'	5.4		
23	Position	1	NS	16		
24	Release	1		2		
25	Grasp	1B		3.5		
26	Position	1	NS	16		
27	Turn		30'	5.6		
28	Turn		30'	6.6		
29	Turn		90'	5.4		
30	Move	B	2	9.2		
31	Move	B	2	9.2		
32	Grasp	4A		7.3		
33	Position	1	NS	16		
34	Grasp	4A		7.3		
35	Position	3	NS	53.4		
36	Release	1		2		
37	Move	B	14	14.6		
38	Grasp	1C2		8.7		
39	Move	B	14	14.6		
40	Apply Pressure	APA		10.6		
41	Apply Pressure	APA		10.6		
42	Apply Pressure	APA		10.6		
43	Apply Pressure	APA		10.6		
44	Apply Pressure	APA		10.6		
45	Move	B	14	14.6		
46	Release	1		2	28.5	Accuracy
47			Total labor time	482.6	792.3	60.91127

APPENDIX K

MTM assessment result for analysis (Set 2)

Number	type	class		distance		TMU		
1	Reach	B			12	12.9		
2	Grasp	1B				3.5		
3	Move	B			12	13.4		
4	Release		1			2		
5	Reach	B			12	12.9		
6	Move	B			24	20.6		
7	Apply Pressure	APA				10.6		
8	Move	B			8	10.6		
9	Release		1			2		
10	Move	B			8	10.6		
11	Grasp	1B				3.5		
12	Apply Pressure	APA				10.6		
13	Move	B			8	10.6		
14	Release		1			2		
15	Move	B			8	10.6		
16	Grasp	1B				3.5		
17	Move	B			8	10.6		
18	Position		1	NS		16		
19	Release		1			2		
20	Apply Pressure	APA				10.6		
21	Reach	B			4	6.4		
22	Grasp	1B				3.5		
23	Release		1			2		
24	Grasp	1B				3.5		
25	Move	B			4	6.9		
26	Grasp	Transfer				5.6		
27	Move	B			6	8.9		
28	Position		1	NS		16		
29	Release		1			2		
30	Apply Pressure	APA				10.6		
31	Move	B			14	14.6		
32	Grasp	1C2				8.7		
33	Apply Pressure	APA				10.6		
34	Apply Pressure	APA				10.6		
35	Apply Pressure	APA				10.6		
36	Move	B			14	14.6		
37	Apply Pressure	APA				10.6		
38	Apply Pressure	APA				10.6		
39	Apply Pressure	APA				10.6		
40	Apply Pressure	APA				10.6		
41	Apply Pressure	APA				10.6		
42	Apply Pressure	APA				10.6		
43	Apply Pressure	APA				10.6		
44	Reach	B			14	14.4		
45	Apply Pressure	APA				10.6		
46	Apply Pressure	APA				10.6		
47	Apply Pressure	APA				10.6		
48	Apply Pressure	APA				10.6		
49	Apply Pressure	APA				10.6		
50	Apply Pressure	APA				10.6		
51	Apply Pressure	APA				10.6		
52	Apply Pressure	APA				10.6		
53	Apply Pressure	APA				10.6		
54	Apply Pressure	APA				10.6		
55	Apply Pressure	APA				10.6		
56	Apply Pressure	APA				10.6		
57	Move	B			14	14.6		
58	Apply Pressure	APA				10.6		
59	Move	B			14	14.6		
60	Apply Pressure	APA				10.6		
61	Apply Pressure	APA				10.6		
62	Apply Pressure	APA				10.6		
63	Apply Pressure	APA				10.6		
64	Apply Pressure	APA				10.6		
65	Apply Pressure	APA				10.6		
66	Apply Pressure	APA				10.6		
67	Apply Pressure	APA				10.6		
68	Apply Pressure	APA				10.6		
69	Apply Pressure	APA				10.6		
70	Move	B			14	14.6		
71	Release	1				2	42	Acurracy
72				Total labor time		692.4	1167.6	59.30113

APPENDIX L

MTM assessment result for analysis (Set 3)

Number	type	class	distance	TMU		
1	Reach	B	14	14.4		
2	Apply Pressure	APA		10.6		
3	Grasp	1B		3.5		
4	Apply Pressure	APA		10.6		
5	Move	B	14	14.6		
6	Move	B	22	19.4		
7	Move	B	8	10.6		
8	Move	B	10	12.2		
9	Release	1		2		
10	Apply Pressure	APA		10.6		
11	Apply Pressure	APA		10.6		
12	Reach	B	10	11.5		
13	Grasp	1C2		8.7		
14	Move	B	10	12.2		
15	Apply Pressure	APA		10.6		
16	Apply Pressure	APA		10.6		
17	Apply Pressure	APA		10.6		
18	Apply Pressure	APA		10.6		
19	Apply Pressure	APA		10.6		
20	Apply Pressure	APA		10.6		
21	Apply Pressure	APA		10.6		
22	Apply Pressure	APA		10.6		
23	Apply Pressure	APA		10.6		
24	Apply Pressure	APA		10.6		
25	Apply Pressure	APA		10.6		
26	Apply Pressure	APA		10.6		
27	Move	B	10	12.2		
28	Release	1		2	14	Accuracy
29			Total labor time	292.9	389.2	75.25694

APPENDIX M

Table 2. Examples of simpler observational methods

Reference	Technique	Main features	Function
[29]	OWAS	Time sampling for body postures and force	Whole body posture recording and analysis
[30]	Checklist	Assessment of legs, trunk and neck for repetitive task	Checklist for evaluating risk factors
[31]	RULA	Categorization of body postures and force, with action levels for assessment	Upper body and limb assessment
[32]	NIOSH Lifting Equation	Measurement of posture related to biomechanical load for manual handling	Identification of risk factors and assessment
[33]	PLIBEL	Checklist with questions for different body regions	Identification of risk factors
[34]	The Strain Index	Combined index of six exposure factors for work tasks	Assessment of risk for distal upper extremity disorders
[35]	OCRA	Measures for body posture and force for repetitive tasks	Integrated assessment scores for various types of jobs
[36]	QEC	Exposure levels for main body regions with worker responses, and scores to guide intervention	Assessment of exposure of upper body and limb for static and dynamic tasks
[37]	Manual Handling Guidance, L23	Checklists for task, equipment, environment and individual risk factors	Checklist for identifying risk factors for manual handling
[38]	REBA	Categorization of body postures and force, with action levels for assessment	Entire body assessment for dynamic tasks
[39]	FIOH Risk Factor Checklist	Questions on physical load and posture for repetitive tasks	Assessment of upper extremities
[40]	ACGIH TLVs	Threshold limit values for hand activity and lifting work	Exposure assessment manual work
[41]	LUBA	Classification based on joint angular deviation from neutral and perceived discomfort	Assessment of postural loading on the upper body and limbs
[42]	Upper Limb Disorder Guidance, HSG60,	Checklist for ULD hazards in the workplace	Assessments of ULD risk factors
[43]	MAC	Flow charts to assess main risk factors to guide prioritization and intervention	Assessment of risk factors for individual and team manual handling tasks

APPENDIX N

Strain Index Scoring Sheet

Analysis Date: 29/3/13 Location: Sidmann Composite Sdn Bhd.

Analyst: Lim Tjon Yong Job/Task Desc.: Mat brushing

Risk Factor	Rating Criterion	Observation	Multiplier	Left	Right
Intensity of Exertion (Borg Scale)	Light	Barely noticeable or relaxed effort [0-2]	1	1	1
	Somewhat Hard	Noticeable or definate effort [3]	3		
	Hard	Obvious effort; unchanged expression [4-5]	6		
	Very Hard	Substantial effort; changed expression [6-7]	9		
	Near Maximal	Uses shoulder or trunk for force [8-10]	13		
Duration of Exertion (% of Cycle)	< 10%		0.5	$\frac{28.5}{28.5} \times 100 = 100\% = 3$	$\frac{22.5}{285} \times 100 = 78\% = 2$
	10-29%		1.0		
	30-49%		1.5		
	50-79%		2.0		
	>80%		3.0		
Efforts per Minute (If duration of exertion is 100%, then Efforts/Minute multiplier should be set to 3.0)	< 4		0.5	3	0.5
	4-8		1.0		
	9-14		1.5		
	15-19		2.0		
	≥ 20'		3.0		
Hand/Wrist Posture	Very Good	Perfectly neutral	1.0	1.5	1.5
	Good	Near neutral	1.0		
	Fair	Non-neutral	1.5		
	Bad	Marked deviation	2.0		
	Very Bad	Near extreme	3.0		
Speed of Work	Very Slow	Extremely relaxed pace	1.0	1.0	1.0
	Slow	Taking one's own time	1.0		
	Fair	Normal speed of motion	1.0		
	Fast	Rushed, but able to keep up	1.5		
	Very Fast	Rushed and barely/unable to keep up	2.0		
Duration of Task per Day (Hours)	< 1		0.25	0.25	0.25
	1 < 2		0.50		
	2 < 4		0.75		
	4 ≤ 8		1.00		
	> 8		1.50		
Results: Find the product of the six multipliers to obtain the SI score	SI ≤ 3	Job is probably safe		3.375	0.375
	3 < SI < 7	Job may place individual at increased risk for distal upper extremity disorders			
	7 ≤ SI	Job is probably hazardous			

APPENDIX O

REBA

Rapid Entire Body Assessment (REBA) Date: 29 / 03 / 2013

Task	Analyst
Mat brushing	Lim Tien Yong

Group A		
Posture/Range	**Score**	**Total**
Trunk		2
Upright	1	If back is twisted or tilted to side: +1
Flexion: 0-20° Extension: 0-20°	2	
Flexion: 20-60° Extension: >20°	3	
Flexion: >60°	4	
Neck		2
Flexion: 0-20°	1	If neck is twisted or tilted to side: +1
Flexion: >20° Extension: >20°	2	
Legs		1
Bilateral Wt Bearing; Walk; Sit	1	Knee(s) Flexion 30-60°: +1
Unilateral Wt Bearing; Unstable	2	Knee(s) Flexion >60°: +2
Score from Table A		3
Load / Force		0
< 5 kg < 11 lb	0	Shock or Rapid Buildup: +1
5 - 10 kg 11 - 22 lb	1	
> 10 kg > 22 lb	2	
Score A [Table A + Load/Force Score]		3
Activity		2
One or more body parts are static for longer than 1 minute		+1
Repeat small range motions, more than 4 per minute		+1
Rapid large changes in posture or unstable base		+1

Group B			
Posture/Range	**Score**	**Total: Left and Right**	
Upper Arms (Shoulders)		L 1	1 R
Flexion: 0-20° Extension: 0-20°	1	Arm Abducted / Rotated: +1	
Flexion: 20-45° Extension: >20°	2	Shoulder Raised: +1	
Flexion: 45-90°	3	Arm Supported: -1	
Flexion: >90°	4		
Lower Arms (Elbows)		L 1	1 R
Flexion: 60-100°	1	No Adjustments	
Flexion: <60° Flexion: >100°	2		
Wrists		L 1	1 R
Flexion: 0-15° Extension: 0-15°	1	Wrist Deviated / Twisted: +1	
Flexion: >15° Extension: >15°	2		
Score from Table B		L 1	1 R
Coupling		L 1	1 R
Good	0	No Adjustments	
Fair	1		
Poor	2		
Unacceptable	3		
		Left	Right
Score B [Table B + Coupling Score]		L 2	2 R
Score C (from Table C)		L 3	3 R
Activity Score		L 2	2 R
REBA Score [Score C + Activity Score]		L 5	5 R

APPENDIX P

REBA

Rapid Entire Body Assessment (REBA) Date: 25 / 04 / 2013

Task	Analyst
Mat brushing (proposed)	Lim Tien Yong

Group A

Posture/Range	Score	Total
Trunk		1
Upright	1	If back is twisted or tilted to side: +1
Flexion: 0-20° Extension: 0-20°	2	
Flexion: 20-60° Extension: >20°	3	
Flexion: >60°	4	
Neck		1
Flexion: 0-20°	1	If neck is twisted or tilted to side: +1
Flexion: >20° Extension: >20°	2	
Legs		1
Bilateral Wt Bearing; Walk; Sit	1	Knee(s) Flexion 30-60°: +1
Unilateral Wt Bearing; Unstable	2	Knee(s) Flexion >60°: +2
Score from Table A		1
Load / Force		0
< 5 kg < 11 lb	0	Shock or Rapid Buildup: +1
5 - 10 kg 11 - 22 lb	1	
> 10 kg > 22 lb	2	
Score A [Table A + Load/Force Score]		1
Activity		2
One or more body parts are static for longer than 1 minute	+1	
Repeat small range motions, more than 4 per minute	+1	
Rapid large changes in posture or unstable base	+1	

Group B

Posture/Range	Score	Total: Left (L)	Total: Right (R)
Upper Arms (Shoulders)		1	1
Flexion: 0-20° Extension: 0-20°	1	Arm Abducted / Rotated: +1	
Flexion: 20-45° Extension: >20°	2	Shoulder Raised: +1	
Flexion: 45-90°	3	Arm Supported: -1	
Flexion: >90°	4		
Lower Arms (Elbows)		1	1
Flexion: 60-100°	1	No Adjustments	
Flexion: <60° Flexion: >100°	2		
Wrists		1	1
Flexion: 0-15° Extension: 0-15°	1	Wrist Deviated / Twisted: +1	
Flexion: >15° Extension: >15°	2		
Score from Table B		1	1
Coupling		1	1
Good	0	No Adjustments	
Fair	1		
Poor	2		
Unacceptable	3	Left	Right
Score B [Table B + Coupling Score]		2	2
Score C (from Table C)		1	1
Activity Score		2	2
REBA Score [Score C + Activity Score]		3	3

APPENDIX Q

REBA

Table A

		Trunk				
		1	2	3	4	5
Neck = 1	Legs					
	1	1	2	2	3	4
	2	2	3	4	5	6
	3	3	4	5	6	7
	4	4	5	6	7	8
Neck = 2	Legs					
	1	1	3	4	5	6
	2	2	4	5	6	7
	3	3	5	6	7	8
	4	4	6	7	8	9
Neck = 3	Legs					
	1	3	4	5	6	7
	2	3	5	6	7	8
	3	5	6	7	8	9
	4	6	7	8	9	9

Table B

		Upper Arm					
		1	2	3	4	5	6
Lower Arm = 1	Wrist						
	1	1	1	3	4	6	7
	2	2	2	4	5	7	8
	3	2	3	5	5	8	8
Lower Arm = 2	Wrist						
	1	1	2	4	5	7	8
	2	2	3	5	6	8	9
	3	3	4	5	7	8	9

Table C

		Score A											
		1	2	3	4	5	6	7	8	9	10	11	12
Score B	1	1	1	2	3	4	6	7	8	9	10	11	12
	2	1	2	3	4	4	6	7	8	9	10	11	12
	3	1	2	3	4	4	6	7	8	9	10	11	12
	4	2	3	3	4	5	7	8	9	10	11	11	12
	5	3	4	4	5	6	8	9	10	10	11	12	12
	6	3	4	5	6	7	8	9	10	10	11	12	12
	7	4	5	6	7	8	9	9	10	11	11	12	12
	8	5	6	7	8	8	9	10	10	11	12	12	12
	9	6	6	7	8	9	10	10	10	11	12	12	12
	10	7	7	8	9	9	10	11	11	12	12	12	12
	11	7	7	8	9	9	10	11	11	12	12	12	12
	12	7	8	8	9	9	10	11	11	12	12	12	12

REBA Decision

REBA Score	Risk Level
1	Negligible
2 - 3	Low
4 - 7	Medium
8 - 10	High
11 - 15	Very High

APPENDIX R

Worker	Overall height	Shoulder height	Elbow height	Working Experience
Aizuddin	165cm	130cm	95cm	Part time
Shukri	167cm	140cm	100cm	Part time
Kamaludin	168cm	138cm	99cm	Part time
M.Fumal	165cm	140cm	100cm	1 yrs +

APPENDIX S

Bill of Material for Ergonomics Footrest	
Type of materials	Quantity
Hollow square 1” (10”)	2
Hollow square 1” (14”)	2
Hollow square 1” (21.5”)	2
Hollow square 1” (19.5”)	2
Hollow square ½” (18”)	10
Solid rod ½” (23”)	2
Solid rod ½” (3”)	12
Rubber mat 20” x 19”	1