‘MANUFACTURING DESIGN FOR PRODUCTIVITY’: OPTIMIZATION OF ASSEMBLY LINE FOR AIR CONDITIONING CONTROL PANELS

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Industrial Design

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June 2006
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ACKNOWLEDGEMENTS

I would like to thank my supervisor Assoc. Prof. Dr. H. Murat GÜNAYDIN firstly for his advices, critics and supports during the study. His patiently guidance putting forward valuable ideas allowed me to accomplish this thesis.

I must thank Asst. Prof. Dr. Yavuz SEÇKİN for his invaluable support and motivation during my education.

Finally I wish to my express my special thanks to my family, for their supports and encouragement throughout my life and for always motivating me towards success.

ABSTRACT

‘MANUFACTURING DESIGN FOR PRODUCTIVITY’: OPTIMIZATION OF ASSEMBLY LINE FOR AIR CONDITIONING CONTROL PANELS

This thesis investigates ‘Manufacturing design for productivity’ surveying a case study of an assembly line for air conditioning control panels. The main aim is to investigate the possibilities of operational improvement on the production time in a cost-effective manner. The specific objective of this study is to investigate the relationship between manufacturing design and productivity issues. In order to achieve the objective of this study, a methodology has been developed. First a thorough literature survey is conducted. The use of methods engineering in the factory system is explained, then the relationships between analytical techniques of methods engineering are discussed. Then examples related to subject are investigated. Later on, an assembly line is selected as the case study. An ex-assembly is redesigned by using the concepts of methods engineering. Then both cases are analyzed and discussed in terms of their output capacity and manufacturing time. After the analysis of MTM for redesigned assembly line it is observed that we can reduce production cycle time 20 % at the end of this study. And this development project has been chosen for investment. At the end of this project, we increased the production quantity from 600 pcs. to 800 pcs. Because efficiency of workers have increased with the redesigned assembly line, production of the goods of quantity increased 13 % more than originally calculated. The new assembly line is reduce the operators waiting time and increases their efficiency. The ex-assembly line was covering 13,5m^2 square it reduce to 3,6 m^2. Finally, because of efficiency and productivity increase of this study, totally we observed 33 % production increase for the same period of time. By the standardization and the elimination of the operations, and reducing the labor cost the factory could increase its competitive strength.

ÖZET

‘VERİMLİLİK İÇİN ÜRETİM TASARIMI’: KLİMA KONTROL PANELİ MONTAJ BANDI OPTİMİZASYONU

Bu tez üretimdeki verimliliğin arttırılması amacıyla klima control paneli üretimini örnek alarak bu sektördeki verimlilik artırma çalışmalarını tasarımın da katkılarıyla inceler. Ana amaç, operasyonel geliştirmeler ile üretim çevrim zamanını en etkin maliyetli hale getirebilmektir. Bu amaç doğrultusunda tez, üretimsel tasarım ve verimlilik kavramları arasındaki ilişkiyi inceler. Çalışmanın amacı doğrultusunda oluşturulan yöntem öncelikle geniş bir literatür araştırması, bu araştırmalar doğrultusunda method mühendisliğinin fabrika sistemlerinde açıklanarak analitik tekniklerinin açıklanması, ardından konu ile ilgili örneklerin bulunup özetlenmesi, mevcut bir montaj bandının geliştirelecek proje olarak seçilmesi ve method mühendisliği yardımıyla tamamlanan çalışma sonuçlarının analiz edilerek üretim kapasiteleri ve zamanları açısından karşılaştırılarak yorumlanmasını kapsamaktadır. MTM yönteminin kullanılması ile projenin verimliliği önceden hesaplandı. MTM yöntemi ile yapılan hesaplamalardan sonra analizler sonucunda yeniden tasarlanan aparatlarla yapılandırılan yeni üretim bandında üretim çevrim süresinde 20 % azalma meydana geleceği ortaya konuldu ve geliştirilen montaj bandı projesine yatırım yapılma kararı verildi. Proje sonunda hesplanan 20 % verimlilik artışının operatörlerin de verimliliğinin artması ile üretim miktarındaki artışn 33 %’e yükseldiği görülmüştür. Yeni montaj bandı operatörlerin bekleme zamanlarını ortadan kaldırarak verimliliklerini artırmıştır. Bunun yanında önceden kurulu montaj bandı 13,5m² alanda kurulu ile yeniden tasarlanmış montaj bandı çalışma alanı 3,6 m²’ye düşürülmüştür. Bu çalışmalar sonucunda verimlilik ve üretim miktarlarında eski montaj bandı ile karşılaştırıldığında aynı zaman dilimi içerisinde 33 %’lük bir üretim artışı gerçekleşmiştir. Operasyonların standart hale getirilmesi ve gereksiz operasyonların elenmesi ile işçilik maliyetleri düşürülerek fabrikanın rekabet gücü artırılmıştır.

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CHAPTER 1

INTRODUCTION

Manufacturing design for productivity is a vital part of today's production economy. By the middle of the nineteenth century, the world became aware of new methods of manufacture in the United States that established the fundamental patterns and processes of modern industrial mass-production. These were characterized by large-scale manufacture of standardized products, with interchangeable parts, using powered machine-tools in a sequence of simplified mechanical operations.

Competition among industrial companies is forced them mass-production. Increased workmanship caused high cost and prices. Within competitive prices they must have produce less production time. It may be asked "Is the work being performed rapidly?" or "Is the worker deliberately taking more time than he needs to do his work?" in a production line. The objective of method engineering is to eliminate every unnecessary element or operation and to achieve the quickest and best method of performing those element or operations that are determined necessary.

In today's competitive market environment with decreasing profit margins, companies can no longer achieve success through the mass production of a limited number of products. Some of advantages of the product development can be lined up increased speed in product development, reduction of product development cost, increased product reliability, increased business strategy flexibility.

By the reducing production time, the aims of this study are stated below;

- Standardization of operations by eliminating unnecessary operations
- Increasing quality standards of the product
- Having a chance to cope with competitive market
- Decreasing cost and prices of the product

1.1. Objective of the Study

The objective of this study is to investigate 'Manufacturing design for productivity issues' for the improvement of an existing assembly line. The research is based on a case study which analysis an existing assembly line and redesigns it for productivity increases.

For doing this an air condition assembly line is investigated. Case shows the improvement of an assembly line for air conditions with eliminating unnecessary motions and standardization of operations. The analysis also aims to improve effectiveness and productivity of the assembly line. Furthermore redundancies in the assembly line are identified and eliminated.

1.2. Terminology Use in the Study

In order to better understand the problems related to the assembly line we could define some basics concepts for manufacturing productivity:

<u>Productivity:</u>

Productivity is basically the ratio of the outputs of an enterprice to the inputs (Goodman and Haris 1995). Pritchard (1992) defines productivity as how well a system uses its resources to achieve its goals (effectiveness) or output relative to inputs (efficiency).

<u>Process:</u>

A process (Graham 1996) is a particular series of actions that accomplish something. It has a start point and an end point between which various items (materials, forms, and records) are worked on, usually by a number of different people located in different places and using various equipment. During the process certain items are changed, thus completing the process.

<u>Methods Engineering:</u>

The term “methods engineering” (is used to describe a collection of analysis techniques which focus attention on improving the effectiveness of men and machines. Methods engineering should not be confined to a single industry or business. Because of its great potential, it can be utilized by any function.

Work measurement:

Work measurement is the time requirement to make a product.

In the light of these basic concepts, a literature review on the subject of methods engineering is carried out in the next chapter. State-of-the-art developments in methods engineering is presented.

CHAPTER 2

METHODS ENGINEERING

2.1. The History of Methods Engineering

Technological developments, expanding trade/markets, growing populations created opportunities for merchants and entrepreneurs to invest in new factories by the seventeenth century. This was the beginning of the Industrial Revolution. With it came the need to improve work methods, quality, and productivity. Two important milestones can be identified as the development of the factory system and concepts of scientific management.

2.1.1. The Factory System

Adam Smith, in the eighteenth century advocated making work efficient by means of specialization. He advocated breaking the work down into simple tasks. He saw three advantages of the division of labor;

- The development of skills
- The saving of time
- The possibility of using specialized tools.

Following on rapidly from from Smith changes in the process of manufacturing developed.

After the War of Independence, there was a shortage of musket parts in the United States. Eli Whitney proposed the manufacturing of muskets by means of using interchangeable parts. Though the idea was viewed with initial skepticism, his process was successful in producing large quantities of interchangeable parts. Thus was born the process of tooling uf for production. At this time Whitney developed and used techniques such as cost accounting and quality control.

About 1830, Charles Babbage (Marrow 1957), an engineer, philosopher and researcher, examined the division of labor in his book *On the Economy of Machinery and Manufacturers*. His work raised important questions about production, organizations and economics. Furthermore the foundation of scientific management was laid by F.Taylor in 1880's just after the formation of the firs factory systems.

2.1.2. Scientific Management

Rapid developments of factory systems are forced the development of scientific management. F. Taylor, Frank and Lillian Gilbert along with C. Bedaux had contributed the methods of scientific management.

Frederick Winslow Taylor

The first systematic approach to methods improvement was taken by Frederick W. Taylor in 1883. Taylor (Sandore 1997) divided a task into individual work elements and studied each element separately; the term 'time study' first appears in the writings of Taylor. He was the first to apply the scientific approach to engineering better work methods.

The four objectives of management under scientific management were as follows:

- The development of a science for each element of a man's work to replace the old rule-of-thumb methods.
- The scientific selection, training and development of workers instead of allowing them to choose their own tasks and train themselves as best they could.
- The development of a spirit of hearty cooperation between workers and management to ensure that work would be carried out in accordance with scientifically devised procedures.
- The division of work between workers and the management in almost equal shares, each group taking over the work for which responsibility largely rested with the workers. Self-evident in this philosophy are organizations arranged in hierarchy, systems of abstract rules and impersonal relationships between staff.

Taylor’s impact has been so great because he developed a concept of work design, work-measurement, production control and other functions, that completely changed the nature of industry. Before scientific management, such department as work study, personel, maintenance and quality control did not exist.

Taylor's core values: the rule of reason, improved quality, lower costs, higher wages, higher output, labor-management cooperation, experimentation, clear tasks and goals, feedback, training, mutual help and support, stress reduction, and the careful selection and development of people. He was the first to present a systematic study of interactions among job requirements, tools, methods, and human skill, to fit people to jobs both psychologically and physically, and to let data and facts do the talking rather than prejudice, opinions, or egomania.

Frank and Lillian Gilbert

A somewhat more searching analysis was being developed about the same time by Frank B. and Lillian M. Gilbert. Their attention was directed to subdividing a specific task into what they regarded as the most fundamental elements of movement, studying these elements separately and in relation to one another, and then rebuilding the task with the elimination of what they regarded as wasteful elements. This synthesis of the remaining elements was arranged to provide what was regarded as the best combination and sequence. The Gilbreths referred to their work as motion study. From the beginning, the Gilbreths showed an appreciation of rhythm and automaticity not possessed by Taylor. Taylor, it is true, had considered processes and motions roughly, but it was the Gilbreths who indicated their full significance.

From the doctrines of Taylor and the Gilbreths, there followed rapid developments in machinery and technology and with the improvement of materials came the moving assembly line. The first production assembly line is found by Henry Ford in the car factory system.

The Production Assembly Line

Towards the end of the nineteenth century the internal combustion engine was invented, leading to the development of the motor car. These was a move towards streamlining production, and the first assembly line method of manufacture can probably be attributed to the mail order factory of Sears and Reobuck of America.

More famous was, of course, Henry Ford. His car factory in the United States is the best example of the change to modern assembly-line techniques. Before the ‘line’ was set up each car chassis was assembled by one man, taking a time of about twelve and a half hours.

Eight months later with standardization and division of labor, the total labor time had been reduced to just ninety-three minutes per car.

Charles Bedaux

In the field of time study, Charles E. Bedaux had been busy since 1911 experimenting with the idea of measuring all human physical work in terms of common unit. Bedaux introduced the concept of rating assessment in timing work.

He is also known for extending the range of techniques employed in work study which included value analysis.

The next development or modification in this subject was work simplification. Its originator, Allan H. Mogensen, was an industrial engineer from Cornell University. About 1930, he defined work simplification as the organized application of common sense to finding better and easier ways of doing every job, from eliminating waste motion in minor hand operations to complete rearrangement of plant layout. Every employee was to be taught to ask ‘Why?’ about everything he did and encouraged to use initiative in furthering savings of time, energy, and material.

Although methods improvement and work simplification studies had been conducted by pioneers in the field of work methods, it was not until the 1930s that H. B. Maynard and his associate, G. J. Stegemerten, applied the name “methods engineering” to a coordinated and systematic approach to improving work methods. Maynard and Stegemerten recognized that the common goal of all workers in this field was to secure maximum labor effectiveness. They also recognized that this could not be secured by isolated studies of operators’ movements, work standards, increased effort, or incentives, but by a combination of proven work study techniques, scientifically applied.

2.2. Analytical Techniques of Methods Engineering

Scientific management used analytical techniques for methods engineering. Methods engineering refers not only to the establishment of the method itself, but also to the standardization of all aspects of the job. The methods engineer has the disposal a wide variety of analytical techniques which can be used either individually or in combination, depending upon the depth of study desired.

The key to the successful use of each methods engineering techniques lies in the development of a questioning attitude; these techniques are tools with which the analyst can systematically question and analyze every aspect of a process.

By carefully selecting the methods engineering technique to be used, the methods engineer can regulate the depth and concentration of study; thus he can select a study technique which will provide a depth of analysis that is proportional to the potential cost savings.

Major methods engineering techniques include process charts, operation analysis, motion study, work sampling, work measurement, and value engineering.

2.2.1. Process Charts

It is a general understanding that the business processes are the work we do. And, if we want to be better at what we do, we need to look at our processes. Without a method and good tools, good intent is often squandered. We need to look at our processes in more than a cursory fashion. We need to look at them in detail and understand the details. When we don't understand the details, it is easy to miss inefficiencies. When we don't understand the details, we may be enabling subversive or counterproductive activity. On the other hand, when our processes become transparent, it is difficult to not see the problems.

If we want to improve our processes, we need to understand them in detail by reviewing and analyzing detail process charts. Simply talking about processes won't cut it.

2.2.1.1. Operation Process Charts

An operation process chart shows only the operations and inspections performed during a process. Every business has basic cycles that govern the way that paper is processed, parts are manufactured, and decisions are made. They may be documented in the form of procedures or routings.

A customer order cycle begins with the placement of an order by a customer. It ends when you are finally paid for goods or services rendered. But there are activities in between the two events that consume time.

When a cycle ends, a lot of non-value adding time has been consumed that may constitute 90-95 percent of total time. Some of the time is lost in travel, some is lost in the processing backlog, and some may be lost diverting a customer's order to a credit department for release. If you can identify the non-value added time in the cycle, you can devise ways to eliminate the causes.

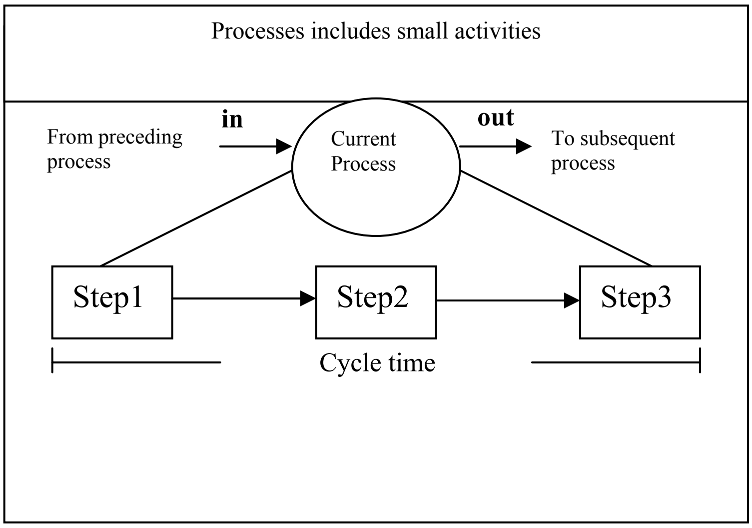


Figure 2.1. Continuous sequential processes consume enormous amounts of time

(Source: Maynard 1984)

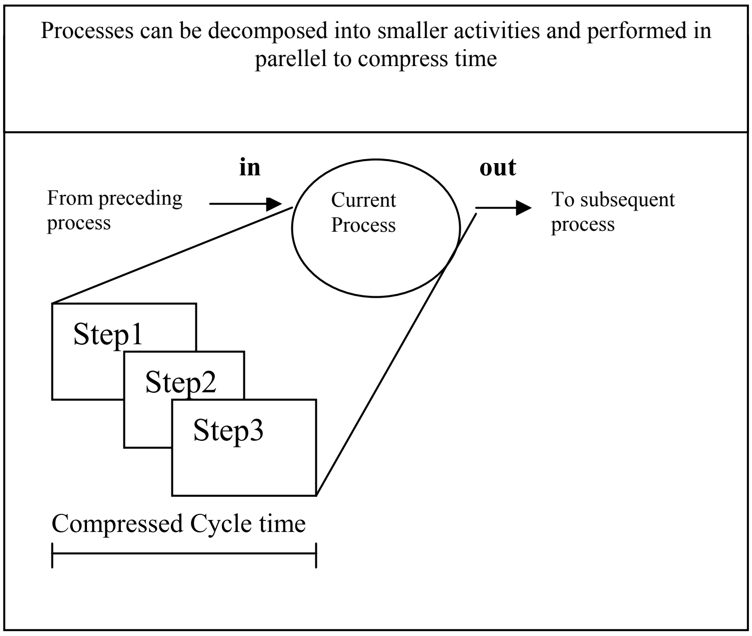


Figure 2.2. Compressed Cycle time by evaluating unnecessary operations

(Source: Maynard 1984)

Mapping process flow is a fundamental step in reducing total cycle times. Mapping the flow and tracking time for each of the events provides a basis for analysis. The process is not difficult, however it is time consuming. It provides a step by step image of work flow, systems, procedures, and volumes. It reveals the relationships between the tasks.

Extending this approach to the entire supply chain and focusing in on the mainstream activities that add value is key. Each of the steps can be further decomposed into smaller activities. By providing the output, such as transferring information, from smaller activities much sooner to the subsequent smaller activities, time can be compressed.

The greatest advantage of an operation process chart is its simplicity; it enables the methods engineer to visualize the relationship between operations or processes without showing the sometimes confusing material handling activities.

2.2.1.2. Flow Process Charts

Flow process charts are similar to operation process charts, but they include material handling and storage activities. A process flow chart visually records the steps, decisions and actions of any process (old or proposed) - manufacturing or service. The chart is an "abstraction" it defines (Jarvis 2003) the process/system; its key points, activities and role performances. For a new process - the chart is a "model" - a blue-print. We can imagine the process working before spending on building and installation work. The chart/model is an important project development and documentation tool.

A process flow chart depicts a process sequence succinctly i.e.

- first A is done
- then B
- then if X is present, do C ELSE
- move to D
- check E and when E is complete inspect F.

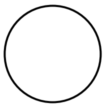
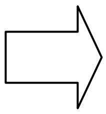
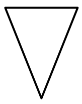
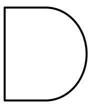
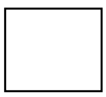
	**Start/End**	This symbol marks the start and end of a process.
	**Operation**	An operation occurs when an object is intentionally changed in any of its physical or chemical characteristics, is assembled or disassembled from another object.
	**Transport**	A transformation occurs when the movement of worker, materials or equipment to and from the process.
	**Storage**	It refers permanent storage points. The material is put away/stored e.g. placed in or issued from a store.
	**Delay**	It refers points of temporary delay or waiting until work can be performed.
	**Inspection**	Inspection is a point in a process where the material must be inspected or workers perform and inspection/test. Thus we can record what the test is

Figure 2.3. Basic symbols for method study
(Source: Kobu 1996)

The chart can be;

- A process outlines (operations and inspections only). This is a "first-cut" chart useful for initial investigations and can be elaborated.
- A material flow process chart - operations, inspections, transport/movement, storage and delays. This charts charts work on an object, its movements to and from the operation, when it is inspected/tested, when stored and when delayed/queued.
- A worker process chart - operations, inspections, transport/movement, delays

2.2.1.3. Basics of Drawing a Flow Chart

Drawing your first process flow chart is not easy. Talk through the process's sequence identifying what is done at each step. Sketch the flow chart in rough - don't worry about errors. Go back to the process and verify against the job in operation. At every stage consults with experienced operators and managers. Observe, re-draft, verify, and change to

- improve understanding of the process
- clarify and challenge the taken for granted aspects
- secure client confirmation
- identify redundancy and unnecessary steps/efforts in the process
- note the quality critical points if zero defects are to be achieved
- identify the inspection and testing routines for each step
- identify the control data to be recorded or confirmed (use exception reporting) at key points.

2.2.1.4. Multiple Activity Charts

Multiple activity process charts graphically present to coordinated working and idle time of two or more man , two or more machines, or any combination of men and machines;for this reason, the multiple activity chart is sometimes called “man and machine chart”. By using a multiple activity chart, the analyst can rearrange the work cycle of either the man or the machine or both, and thus develop a more effective combination of activities.

2.2.2. Operation Analysis

Operation analysis (Maynard 1970) is a procedure used to study the factors that affect the method of performing an operation to achieve maximum overall economy. A thorough examination is made of each of the following ten points of primary analysis:

1. Purpose of operation
2. Design of part
3. Process analysis
4. Inspection requirements
5. Material
6. Material handling
7. Workplace layout, setup,and tool equipment
8. Common possibilities for job improvement
9. Working conditions
10. Method

A look at the steps of the operation analysis approach shown below emphasizes the fact that the technique may be applied to any job and that the principles of operation analysis are not limited in any way by the nature of the work being done.

1. Observe or visualize operation.
2. Ask questions.
3. Estimate degree of improvement or automation possible.
4. Investigate ten approaches to improvement and automation:

a. Design of part or assembly
b. Material specification
c. Process or manufacture
d. Purpose of operation
e. Tolerances and inspection requirements
f. Tools and speed, feed, and depth of cut
g. Equipment analysis
h. Workplace layout and motion analysis
i. Material flow

j. Plant layout

5. Compare old and new methods.

2.2.3. Motion Study

Motion study consists of dividing work into the most basic elements possible and studying these elements seperately and in relation to one another, both qualitatively and quantitavely.

Group I	Group II	Group III
Reach Move Grasp Position Disengage Release Examine Do	Change direction Pre-position Search Plan Balancing delay	Hold Avoidable delay Unavoidable delay Rest to overcome fatigue

Figure 2.4. Motion Study Elements

(Source: Mynard et al. 1948)

Principles of Motion Economy:

- Both hands should work at the same time.
- The hands should work in opposite symmetrical directions.
- Each hand should go through as few motions as possible.
- The work place should be designed to avoid long reaches.
- Avoid using the hand as a holding device.

2.2.4. Work Sampling

The work sampling procedure is based on a small number of chance observations tend to follow the same distribution pattern that actually occurs in the study area. (Barnes 1968)In a work sample study:

- Observing an activity during a fixed duration (e.g., a day) at random intervals to estimate the fraction of time spent directly on some sub-activities of interest
- Applications
  - Ratio delay = % idle time
  - Performance measurement
  - Time standard
- Experimental approach
  - Level of confidence
  - Sample size
  - Accuracy of observations

- The observer randomly samples 60 times in a day and notes that a particular element is performed 12 times.
- Estimate the % of the time that worker spend on this element.
- Calculate the precision of the estimate (at 95% confidence interval)
- Determine the appropriate sample size required for a second set of observations if the acceptable numerical error is 0.02.

2.2.5. Time Study

"Time study is a dark-ages technique, and it's dehumanizing to track someone around with a stopwatch." (Maynard 1948)

Time Study Benefits:

1. Obtains lower unit cost at all levels of production because production is more efficient.
2. Achieves greater output from a given amount of resources.
3. Improves the schedule of work.
4. Acts as the basis for future planning of money, manpower and machines.
5. Continually focuses attention on cost reduction and control.
6. Offers workers a definite objective statement of what is expected of them in a given period.
7. Increases the market and/or profit potential of the firm because of the lower unit cost.

8. Aides in the preparation and adoption of budgets.

9. Provides a management guide to either meet or exceed standards of performance set for their areas of control.

10. Rewards best workers, rather than giving equal compensation for unequal contribution.

11. Places greater emphasis of quality by paying only for the work which passes inspection.

12. Allows individuals the opportunity to set their own pace. By allowing them to do this, they largely determine their own take-home pay.

2.2.6. Methods Time Measurement (MTM) Analysis

Methods time measurement (MTM) is a work measurement procedure which analyzes the basic motions required to perform any manual operation or method and assigns to each motion a predetermined time Standard based upon the nature of the motion.(Krick 1962)

The time required to complete one work cycle (the cycle time) is accomplished by using a stopwatch while observing the worker on the job or playing the video tape at normal speed. This allows for classification of the job into high or low frequency. High frequency is defined as one cycle completed in less than 30 seconds or, if more than 50% of the cycle time is involved performing the same kind of task (referred to as Fundamental Cycle). Low frequency is defined as greater than 30 seconds to complete one cycle, or if less than 50% of the cycle time is involved performing the same kind of fundamental cycle. It has been reported that workers in high frequency repetitive work positions have a 31% greater risk for tendinitis compared to workers in low frequency jobs (Anderson 1988).

Breakdown of Elemental Motions

1. **Reach:** Reach is an unloaded hand or finger motion.

2. **Position:** Position is a small motion needed when aligning an object to be released at when the motion is done.

3. **Release:** Release is a distinct motion of fingers or release of object at end of a motion without any overt movement of fingers.

4. **Disengage:** Disengage is an involuntary motion required when two object come apart after exertion.

5. **Grasp:** Grasp is an overt motion to gain control of object.

6. **Eye-focus travel:** Eye-focus travel is a time for eyes to move and adjust to visualization of object.

7. **Turn-Apply Pressure:** Turn-Apply Pressure is a manipulation of controls, tools, and objects needed to turn an object by rotation about the long axis of the forearm.

8. **Body and Leg/Foot Motion:** Body and Leg/Foot Motion is a transporting the body with values given per step under various circumstances.

9. **Simultaneous Motions:** Simultaneous Motions are performance of more than one motion at same time. Only the greatest of the times is used in the standardized measurement to get a conservative estimate. E.g. use of right and left hand reaching for an object.

2.2.7. Value Engineering

Value engineering (Fallon 1971) is a method for improving product value by improving the relationship between the function of a product and its cost.

Fundemental characteristics of value engineering, which have not changed since Lawrence D. Miles founded the discipline in the 1940's, are:

Value: Deliberately stepping from matters of the fact to matters of value, from what is to what should be.

The Function: concentration on the function of a product or service, rather than the structure of the product or the form of the service-a results- oriented approach.

The Method: a proved sequence, called the job plan, which systematically applies information search patterns and creative techniques to the analysis and improvement of value.

The value engineering approach consists of selecting the Project and accumulating complate cost data. Using the brainstorming technique, alternative methods of accomplishing each function are developed.

2.2.7.1. The Value Task Group

We can examin mainly five catagories and five components of product value which are related with the catagories.

Task group element	*Effect on value*
Customer viewpoint............................	To suit the market
Product design....................................	To create utility
Manufacturing.....................................	To overcome difficulty in attainment
Finance..	To allocate costs
Purchasing..	Three roles: 1- to provide supplier information, 2- to appraise competitive products 3- to ask customer questions

2.2.7.2. Project Selection

The value task group should be tailored to suit the projects, but the Project must be selected to meet their company's most pressing needs.

Table 2.1. Typical Value Task Groups

(Source: Barnes 1968)

Product and industry	*Task group members*
Steam trap	Process control foreman
Process industry	Piping engineer
	Steam engineer
	Buyer
	Cost engineer
TV chassis	Assembly line foreman
Consumer TV industry	Electronic engineer
	Mechanical engineer
	Methods engineer
	Mechanical buyer
Radar	Circuit design engineer
Defence industry	Applications engineer
	Manufacturing engineer
	Elektrical buyer
	Quality engineer

2.3. Systems Used in Methods Engineering

2.3.1. Case A: Henry Ford and founding the first assembly line

Over 100 years ago as a methods engineer Frederick Winslow Taylor’s time studies and “laws and principles” of scientific management changed how workers were paid, introduced a new division of labor and expanded and strengthened the role of management. Frank and Lillian Gilbreth’s motion studies focused on how the work was done, and how to eliminate unneeded, fatiguing steps in any process.

They wanted “flow” manufacturing (Bodec 2004) to take place but they did not want workers to stop and think. And through their work productivity climbed substantially allowing Henry Ford to produce an automobile in four days from iron core to the finished car being put onto the railroad cars. Modern manufacturing was born.

Production didn't take off, however, until Ford applied the methods of Frederick Winslow Taylor, the genius behind The Principles of Scientific Management (1911). According to Taylor (Taylor 1911). in his book, "In the past, the man has been first; in the future the system must be first." He examined each process of a product's production and thought of ways to lessen its manufacturing time. Furthermore, Taylor emphasized management and workers' joint effort in increasing surplus rather than dividing it. More was better. Faster was better. Producing more faster could only lead to one thing: the assembly line.

Founding the first assembly line by Henry Ford, we met mass production which methods engineering is used. Fordizim means to standardize a product and manufacture it by mass means at a price so low that the common man could afford to buy it.

In October, 1913 a revolutionary step was taken in the advancement of factory assembly when Henry Ford unveiled his moving car assembly line. The assembly line certainly changed the face of motor vehicle manufacture. There was an ever growing demand for the car and the new technology was intended to rapidly speed up the production process.

The remarkable birth rate of Model T's was made possible by the most advanced production technology yet conceived. After much experimentation by Ford and his engineers, the system that had evolved by 1913-14 in Ford's new plant in Highland Park, Michigan, was able to deliver parts, subassemblies, and assemblies (themselves built on subsidiary assembly lines) with precise timing to a constantly moving main assembly line, where a complete chassis was turned out every 93 minutes, an enormous improvement over the 728 minutes formerly required. The minute subdivision of labour and the coordination of a multitude of operations produced huge gains in productivity.

Reducing the cycle time price of a model-T reduced from $780 to $360 between 1910-1915. In the 19 years of the Model T's existence, Ford sold 15,500,000 of the cars.

In 1914 the Ford Motor Company with 13,000 employees produced 267,720 cars; the other 299 American auto companies with 66,350 workers produced only 286,770 cars. Ford had 48% of US car market, Company has $100 million in annual sales.

Dr. Shigeo Shingo, an independent consultant, and Taiichi Ohno, vice-president of production at Toyota, restudied the work of Taylor, Ford and the Gilbreth's and clearly understood the power of flow manufacturing. They also discovered a powerful 'missing ingredient," the worker on the factory floor is really the expert on the job, rarely ever asked to be creatively involved in solving problems. To be internationally competitive this waste of human resources had to end.

Shingo and Ohno the creators of The Toyota Production System/Lean like Taylor and Gilbreth wanted both a productive workplace and flow manufacturing. They did not want the worker to stand, wait and attend machines. They wanted workers to use both hands and move continually working multi-machines in the factory.

As Lean was created at Toyota the worker was directly involved:

1- Whenever a problem was detected the worker either pulled a chain or pushed a button to stop the line – yes, they stopped other workers from working. Imagine the power given to a worker to stop others from working. Toyota was serious. Defects will not be passed onto the customer. The worker was asked to immediately detect the cause of the problem, solve it and also get to the root cause so that the problem would not occur again. Toyota wanted the exact same "Flow" as Taylor and Gilbreth. They did not want the worker to think on the job except when a problem occurred. They realized that the worker on the floor has brains and that those brains were required to help solve problems.

2- Toyota also recognized that many problems could not be solved immediately so they asked their workers to come up with small improvement ideas to help solve problems around their work area. In fact, Toyota was getting 70 ideas per worker per year in writing. And Toyota noted for making junk in 1960 became the world's highest quality producer, in fact, the richest automotive company in the world. Today, Toyota's stock is worth more then General Motors, Ford and Chrysler/Benz combined.

Henry Ford's ideal types of Fordist production system included using fixed and dedicated machines in individuals work, rather than turning the employee into a machine. (Hollinshead 1995) With Taylor attempting to prove to the world that there was a science to management and that the quickest way was the best way, he attacked the incompetence of managers for their inefficiencies in running the railroads and factories. Using time and motion studies, Taylor achieved productivity increases of up to 200 per cent. (Dunphy 1998). His thoughts were echoed by others: during a 1910 Interstate Commerce Commission hearing, Louis D. Brandeis argued that US railroads could save a million dollars a day if they introduced scientific management into their operations (Oakes 1996). Taylor showed the world that the methodical and scientific study of work could lead to improved efficiency. He believed that by defining clear guidelines for workers many improvements could be made to the production of goods.

2.3.2. Case B: Design of Operations in Sewing

This study is prepared by University of Maribor, Slovenia. Study is about workloads and standard time norms in garment engineering. The investigations described make possible to find optimal distribution of working elements and zones of reach important for ergonomic designing and/or re-designing of workplaces, which results in considerably reduced level of fatigue in work, optimal quality level, higher degree of utilization of equipment installed and lower manufacturing costs.

Defining time norms in sewing operations:

Operations of sewing consist of hand, machine-hand and machine sub-operations, which, according to the manner of performance and sequence, constitute its structure.

The application of the MTM system makes the work method description quite clear, with accurately defined normal duration, while the regularities and the concept are defined by which a worker of average mental and physical abilities, possessing average level of skills, performs the movements involved in a logical sequence. This method can allso be used to define time norms and design workplaces in garment engineering as early as the phase of designing manufacturing processes and production systems.

Table 2.3 is shows investigation of sewing operation employing the MTM system (1 TMU=3,6*10^2)

Table 2.2 . Sewing operation structure
(Source: Dragcevic et al. 2002)

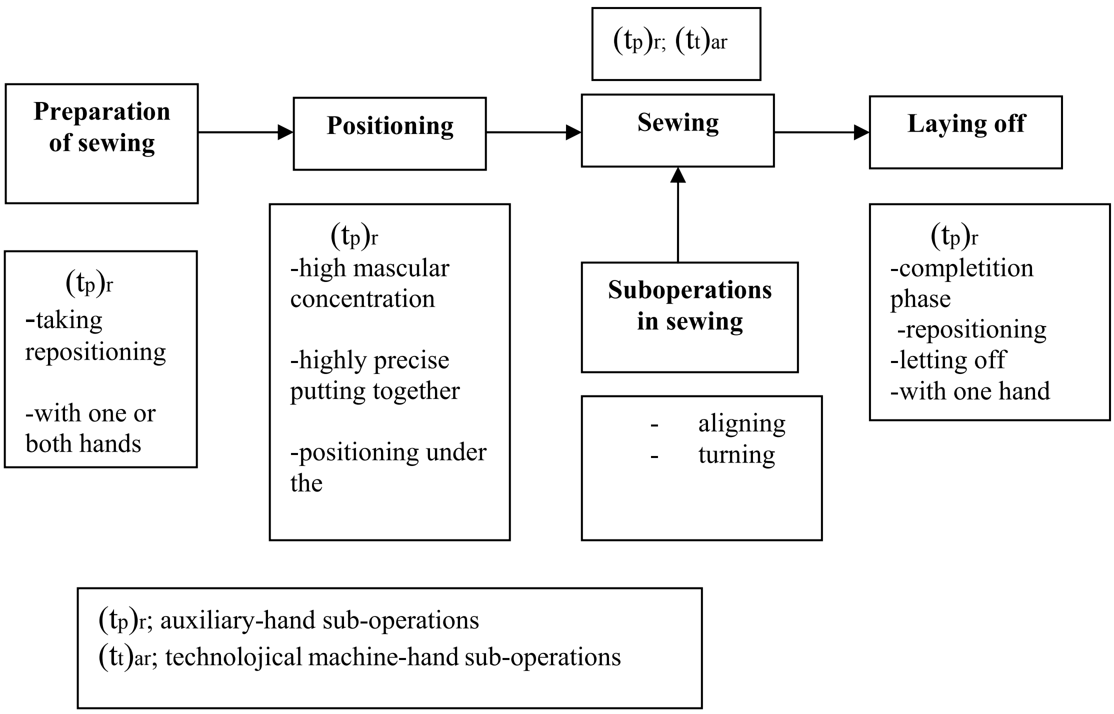


Table 2.3. Preperation of sewing

(Source: Dragcevic et al. 2002)

	MTM WORK ANALYSIS		List no:1
Object of manufacture	Operation:Sewing the breast seam on the ladies’suit		DATE:15/12/1999
Prot. No	Left hand movement description	Symbol TMU Symbol	Right hand movement description
1.	PRERARATION OF SEWING		
1.1.	Take and transport the new upper part to the working zone Layy-off workpiece from the previous cycle		
1.1.1.	Reach for the upper part	R55B 23.7 M80Bm	
1.1.2.		(T90S)	Rotate hand
1.1.3.		(RL1)	Release the workpiece
1.1.4.		Take and transport the new lower part	
1.1.5.		26.9 mR80B	Reach for the lower part
1.1.6.	Grasp the upper part	G5/G2 5.6 G5/G2	Grasp the lower part
1.1.7.	Reach with fingers	R8A 13.3 M30B	Transport the lower part into the working zone
1.1.8.	Grasp the lower part	G5 0 RL2	Release the lower part onto the working zone
1.1.9.	Move fingers forwards	M8A 5.1 G5	Support the lower part
1.1.10.	Release fingers	RL2 0	
1.1.11.	Reach with fingers	R8A 5.5	
1.1.12.	Grasp the upper part	G5 0 ×5	
1.1.13.	Reach with fingers	M8A 5.1	
1.1.14.	Release fingers	RL2 0	
1.1.15.	Transport the upper part	G1B/ M60C 28.7	
		Σ=156.3 TMU (5,6s)	

Table 2.4. Positioning upper and lower parts

(Source: Dragcevic et al. 2002)

2.	POSITIONING UPPER AND LOWER PARTS		
2.1.	Position the upper part	P1SE 5.6 P1SE	Position the lower part
2.2.	Transport the workpiece to the needle	M4C 4.5 M4C	Transport the workpiece to the needle
2.3.	Feet movement	FM 8.5	
2.4.	Position the workpiece under the needle	P1SE 5.6 P1SE	Position the workpiece under the needle
2.5.	Feet movement	FM 8.5	
		Σ=32.7 TMU (1.2s)	

Table 2.5. Sewing the seem

(Source: Dragcevic et al. 2002)

3.	SEWING THE SEEM		
3.1.	Sewing the first segment		
3.1.1.	Feet movement	FM 8.5	
3.1.2.	Sew the seam	tar 87.9 G5	Guide the workpiece in sewing
3.1.3.	Feet movement	FM 8.5	
		Σ=104.9TMU (3.8s)	
3.2.	Breaking with alignment		
3.2.1.	Release the workpiece	RL2 2.0 RL1	Release the workpiece
3.2.2.	Align the workpiece	R20A 7.8 R20A	Align the workpiece
3.2.3.	Grasp the workpiece	G1B 3.5 G1B	Grasp the workpiece
3.2.4.	Align the edges of the upper and lower parts	P2SE 16.2 P2SE	Align the edges of the upper and lower parts
		Σ=29.5TMU (1.1s)	
3.3.	Sewing the second segment		
3.3.1.	Feet movement	FM 8.5	
3.3.2.	Sew the seam	tar 69.7 G5	Guide the workpiece in sewing
3.3.3.	Feet movement	FM 8.5 RL2	Release the workpiece
3.3.4.	Grasp the workpiece	RL1 10.0 R20B	Reach for the workpiece
3.3.5.	Return the hand to a balanced position	R20E 9.2 G1B	Grasp the workpiece
		Σ=105.9TMU (3.8 s)	
Total time needed for the operation:429.3 TMU (15.5s)			

Results and discussion

The technological operation of sewing a front bust seam on a ladies' fashion suit, 52 cm long, performed on a designed workplace on an universal sewing machine BROTHER DB2-B755, equipped with a processing microcomputer designated F-100.

The overall normal time necessary to perform the operation described is 492.3 TMU (15.5s). Machine-hand times in the structure of the sub-operation III are defined following the mathematical model for a pre-programmed maximum sewing speed of 4000 rpm and feed rate of 2.0 mm is 87.9 TMU(3.2s) for the first sewing segment (30-35 cm) and 69.7 TMU (2.5s) for the second one (17-22 cm).

Using the OADM method in investigations, this work can be described as a light physical work (oxygen consumption 0.5-1.0 l/min, with energy consumption of 175 W and brief static loads of lesser intensity). Sight is exposed to considerable loads and high visual concentration is necessary in the course of the sub-operations II and III. Due to the brevity of individual cycles (15.5 s) and high repetitiveness, psychic fatigue is also considerable.

The work is performed in the temperature range between 20.0 and 24.0 ºC , and noise intensity is 70 dB(A). Depending upon the time of being exposed to the above factors, and supposing a working shift of 7.5 h, the ergonomics coefficient for the technological operation in the question is Ker =0.082, or 8.2%. Investigations show that the time norm is 464.5 TMU (16.7s), with an adequate hourly production of 205 cycles/h.

The series of movements described is optimal, consisting at the same time of simultaneous movements of left and right arm, with ergonomically acceptable body posture. The sets of basic movements implemented result in an even rhythm of performing the job and lower fatigue.

These methods are used in optimizing the existing production systems, in educating the workers while practicing the operations, for making preliminary costs estimations etc. The data obtained are precise and reliable, and can be applied to the workers possessing average level of skills, which is quite important for a successful organization of manufacturing processes in garment industry.

2.3.3. Case C: Product Development Strategy

Scrapes Company was established in 1963 as a local earth moving machine maker. In the early nineties, a Japanese competitor entered into its shares pack, until it became a major shareholder in 1995. The company operates in five different market niches: “mini” diggers, “midi” diggers, backhoe loaders, articulated backhoe loaders, skid steer loaders that could be clustered and defined “utility machines” market.

A new product platform introduction requires from about 18 to 24 months. During a platform’s life a “minor change” is usually made (derivative product) requiring 8-12 months development time. Typical modifications are those attaining cost reductions, added functionality and improved manufacturability. The company does not utilize platform teams, although the engineering department is subdivided in two subgroups according to the product lines they develop.

The use of common product planning and supervision implements standardization throughout the product lines. This is possible, thanks to the small dimensions of the engineering function. Component teams are on the contrary occasional.

Product development process:

Innovation generally emanates from the engineering department, since the firm has not got a proper R&D office. Suppliers are therefore often those who suggest innovative solutions. The new product development process (NPD) flow shows a typical ”tollgates” pattern, made up of 4 phases: market searches and concept development, prototype development and test of target performance achievement, prototype enhancement, production ramp-up.

Market searches and concept development: The start up phase is a consequence either of a market search or of a specific request of a customer. The input data for the design phase are expressed in the form of performance values (e.g.: machine power, hoe volume, digging depth, work radius, etc.).After that project teams are constituted, technical feasibility hefted and one product proposal is fostered. The phase ends up with a meeting called ”A” evaluation meeting, in which all functions are involved (general direction, engineering, manufacturing, commercial marketing, finance), and whose aim is the complete evaluation of the product proposal.

Prototype development and test of target performance achievement: Phase 2 is attended by the engineering department (drawings and prototype realization), commercial department (supports engineering in making make-or-buy choices) and manufacturing (helps determining costs through manufacturing cycle costing).After phase 2, the project undergoes another “yes-or-no” tollgate, namely a “B” evaluation meeting (all functions involved as in meeting “A”).The aim of this meeting is to evaluate whether the physical prototype respects the performance targets, set in the previous phase. Three kinds of answers are admitted: the Project is rejected, the product is partially accepted and will undergo a refinement phase, the prototype is fully satisfactory and the production ramp-up authorized.

Prototype enhancement: This is basically an optional phase the project will go trough if the target requirements, evaluated in the “B“ meeting, were only partially satisfied. As a consequence, the functions attended to in the phase are the same as in phase 2, with the only difference being that only some parts of the product have to be redesigned. The phase ends with a ”C” evaluation meeting identical to the “B” meeting.

Production ramp-up: Whenever production has been authorized either in phase 2 or 3, phase 4 is supposed to begin. The product is thus manufactured and sold to the market place. During the production phase, no broad meetings, involving several functions, are scheduled. Contingent problems are hefted in a “D” evaluation meeting, that is a post audit which happens 6 months after the product’s launch. Both technical aspects and market expectation fulfillment are evaluated.

Product development organization

The organization of NPD is basically a weak matrix with relatively strong functions’ weight. One lightweight Project Manager co-ordinates the development process, guaranteeing that projects step forward. The engineering department constitutes 25 people, working in two main substructures that develop different product families. Whenever the firm plans the launch of a new product, a project leader is appointed and resources assigned to the project team. These teams are disbanded when projects end, and engineers assigned to other projects within the substructure they belong to. In this way some knowledge retention is sought for.

Product strategy

Platforms: The definition of the product platform is tightly linked to that of the product family, or product line. Different models of a family are plainly obtained through scaling up and down (in the physical sense of a dimensional scale)of a basic model. The latter is usually the first product of the family to be developed and launched onto the marketplace. The remainder of the product family quickly follows. Though no platform teams operate inside the engineering department, models are developed as plain variations of the reference models, knowledge transfer being assured by common family development planning, eased by small dimensions of teams (everything is developed under single person supervision).Developing a brand new product line requires from 18 to 24 months, while its market life latest from about 5 years for small machines to 10 years for bigger ones. During this period, usually a “minor change” is made (derivative product), lasting for about 2-3 years on the market and requiring 8-12 months to be developed. Typical modifications are those attaining cost reductions, improved manufacturability and added functionality.

Component development and modularization: Within the platform, product shows a large set of common components. Nevertheless there is a discrete commonality between products belonging to different families, obtained through implementation of module sharing and parts standardization. These regard:

- Some visible components in machines of similar weight (e.g.: cockpit);
- Under-body components (engines, servomechanisms, hydraulic and pneumatic components);
- Subassemblies of some machines (e.g.: enter cockpit and hoe in backhoe and articulated backhoe loaders)despite their completely different frame structure.
- A lot of common parts (codes) like pipes, screws, and so forth, are then standardized across families.

Model specific components (those adding functionality to the reference product) are usually bought as “black boxes” from specialized suppliers. The interfaces that suppliers define become compelling for successive development phases.

Development of concepts in methods engineering followed by increases in manufacturing quality and productivity. In the following chapter methodology of this study is explained by use of these methods engineering concepts.

CHAPTER 3

METHODOLOGY

To achieve the objective defined in chapter 2, the following methodology of thesis is developed. Concepts of Methods Engineering are integrated in the methodology to increase productivity of an assembly line.

1. Problem definition.
2. Discussing the productivity is needed for industrial revolution.
3. Literature review on Methods Engineering.
4. Surveying the case studies from Turkey and other countries.
5. Selecting an existing assembly line/area.
6. Evaluating current productivity of the selected assembly line/area.
7. Developing the current state of the assembly line/area with analyzing operations.
8. Comparing the results of both state choices the effective one.
9. Make the new line. Balance the line giving the right operations to the right operators.
10. Evaluating between new and old assembly lines/areas.

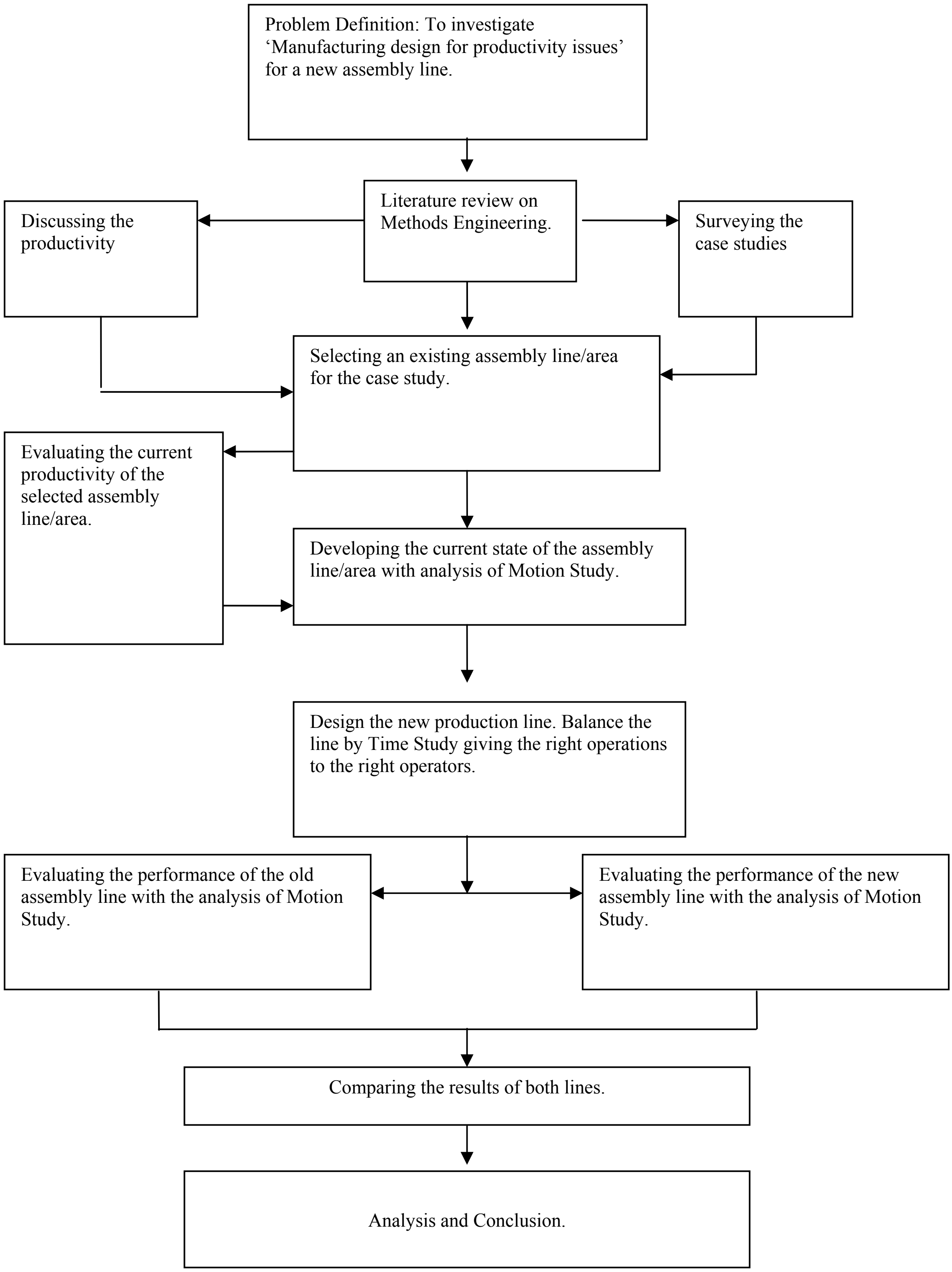


Figure 3.1. Methodology of the study

3.1. Selecting an existing assembly line with analysis of Motion Study

In this case we are examined how the old designed assembly line worked before. It has five different operational areas which are partly assembled. We can summary this assembly line as i stated below:

1- Assembling of connector, metal sheet, fuse and holder
2- Assembling of receiver on to the the metal sheet
3- Assembling of the capacitor with the cables
4- Assembling of the capacitor with the metal sheet
5- Electrical test of the air condition control unit.

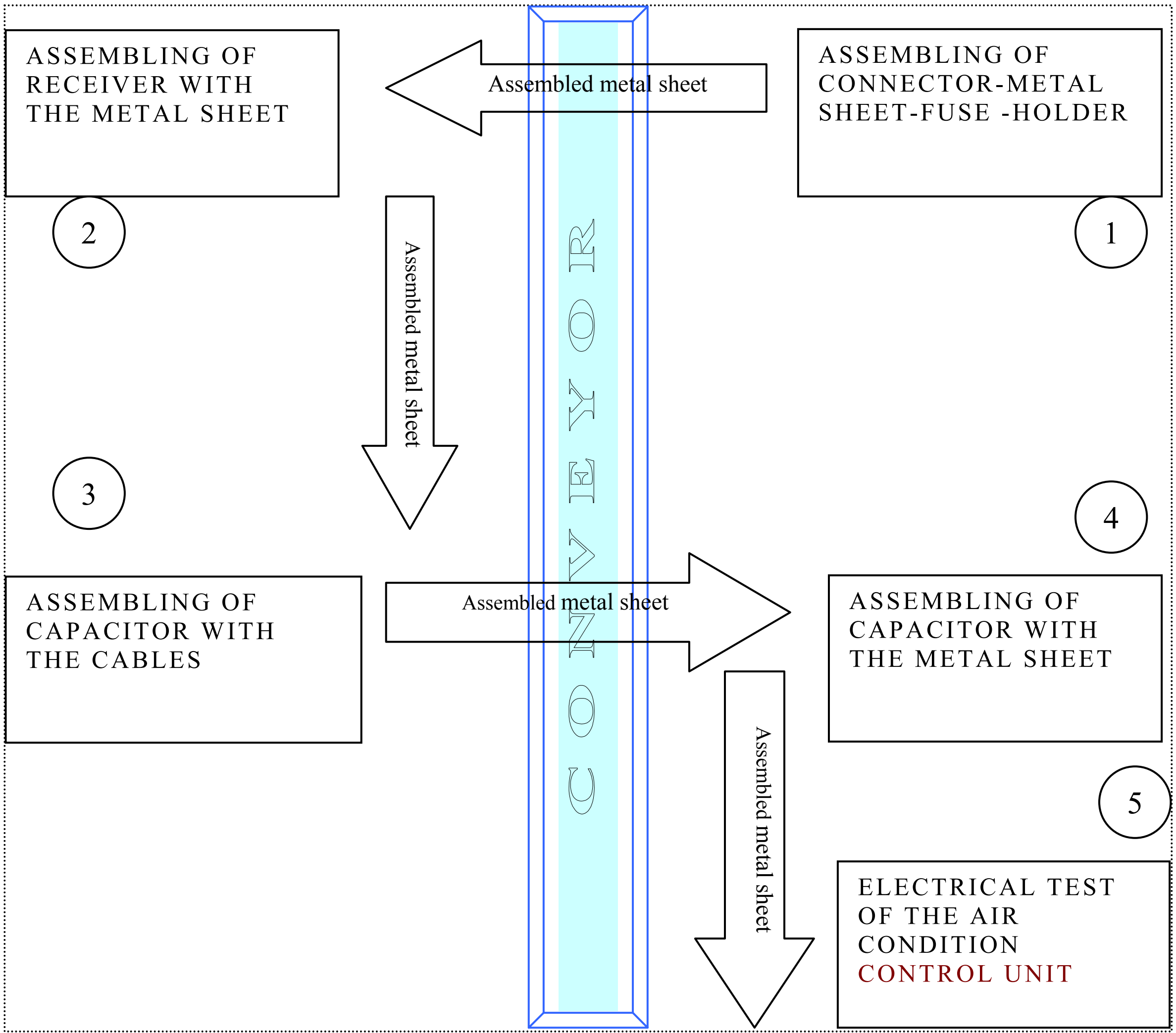


Figure 3.2. Operational scheme of ex-assembly line

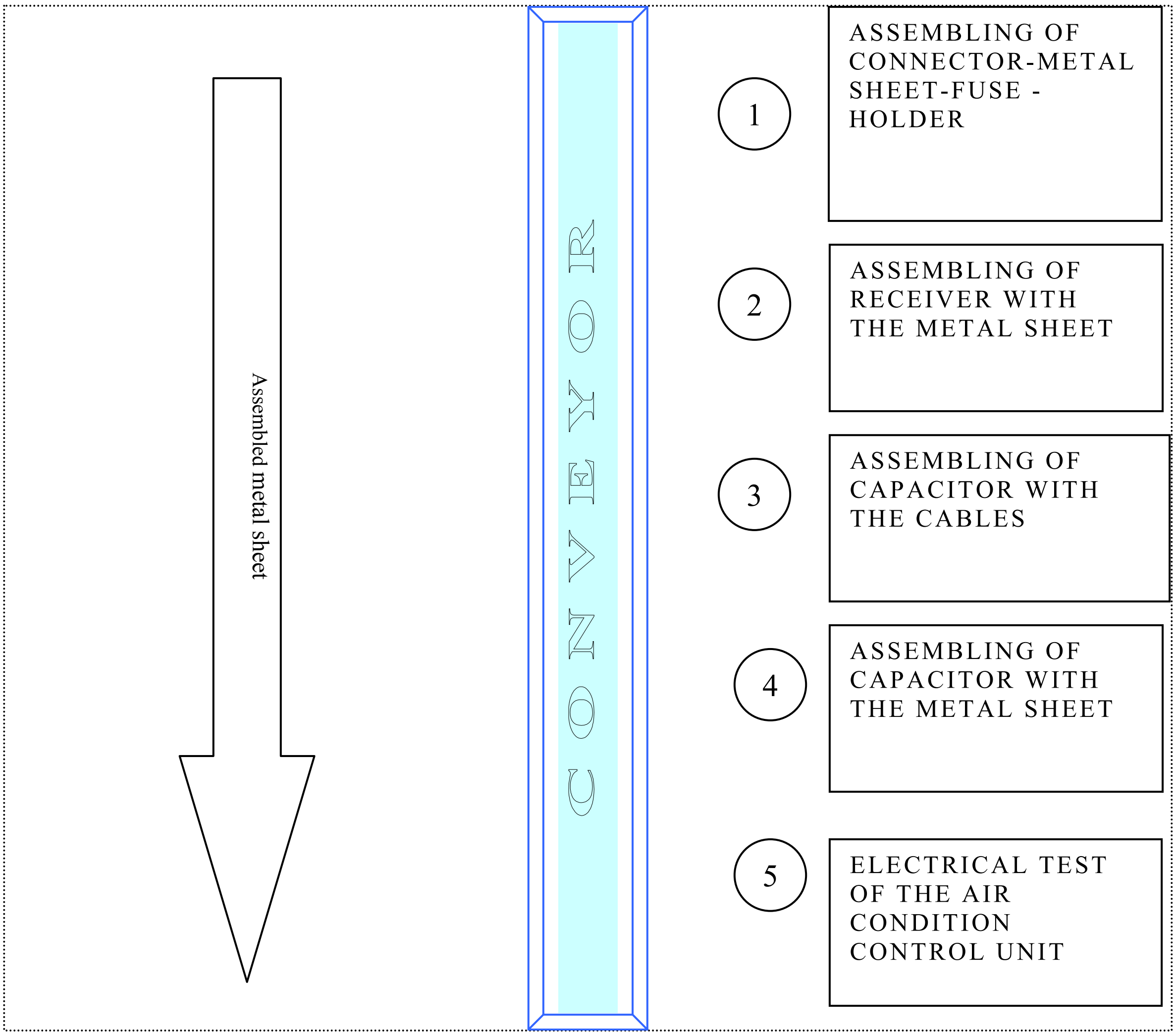
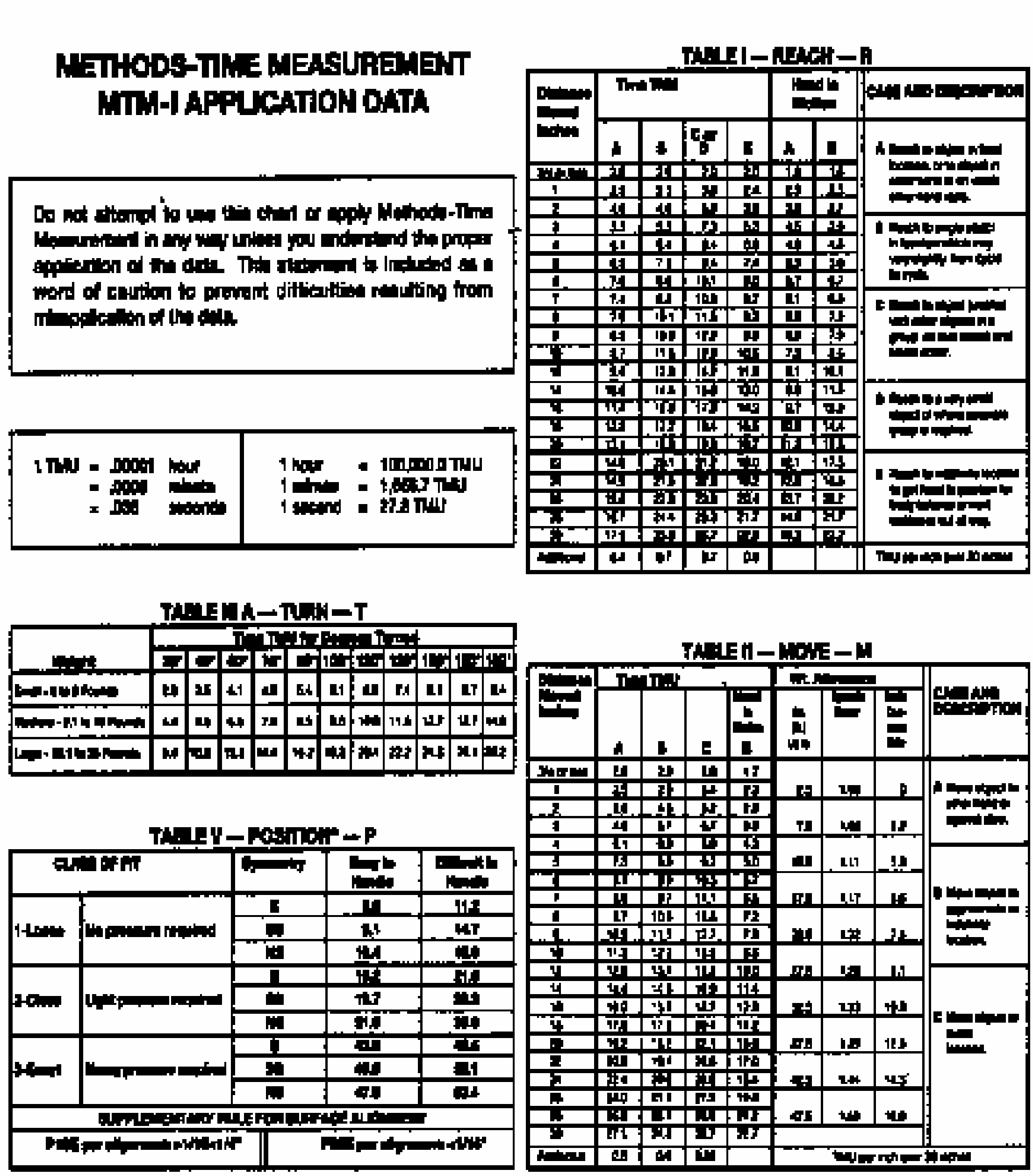


Figure 3.3. Operational scheme of redesigned-assembly line

Because we have to examine all part of the operations one by one, using METHODS-TIME MEASUREMENT DATA SHEET stated below; we can calculate how much time the operations take.

Table 3.1. MTM-1 Application Data

(Source: Maynard 1984)



METHODS-TIME MEASUREMENT
MTM-I APPLICATION DATA

Do not attempt to use this chart or apply Methods-Time Measurement in any way unless you understand the proper application of the data. This statement is included as a word of caution to prevent difficulties resulting from misapplication of the data.

1 TMU = .00001 hour
= .0006 minute
= .036 seconds

1 hour = 100,000.0 TMU
1 minute = 1,666.7 TMU
1 second = 27.8 TMU

TABLE I — REACH — R

TABLE III A — TURN — T

TABLE II — MOVE — M

TABLE V — POSITION* — P

CHAPTER 4

FINDINGS AND ANALYSIS

Ex-assembly line and the redesigned assembly line are evaluated by their output and manufacturing times. By the reducing production time, the aims of this study are showed below. We will analyze how much time we can save by standardization of operations by eliminating unnecessary operations.

4.1. Evaluating the Performance of the Ex Assembly Line with the Analysis of Motion Study

Table 4.1. Assembling of connector, metal sheet, fuse and holder for an air condition control panels

	MTM WORK ANALYSIS		List no:1
Object of manufacture	Operation: AIR CONDITION ASSEMBLY LINE PROCESS		DATE:15/12/2003
Prot. No	Left hand movement description	Symbol TMU Symbol	Right hand movement description
1.	ASSEMBLING OF CONNECTOR-METAL SHEET-FUSE-HOLDER		
1.1.	Take the metal sheet and position on to the apparatus		
1.1.1.	Reach for the metal sheet	R35B 14.2	
1.1.2.	Grasp the metal sheet	G4A 7.3	
1.1.3.	Move it to the apparatus	M35A 14.3	
1.1.4.	Eye travel	ET 15.2	
1.1.4.	Position on to the apparatus	P2SD 21,8 G5	Support the metal sheet
1.1.5.	Apply pressure	APA 10.6	
1.1.6.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=85,4 TMU(0,051min)	

Table 4.2. Assembling of connector group for an air condition control panels (Continued Table 4.1)

1.2	Reach for the connector group	R35C 15.5	
1.2.1.	Grasp the connector group	G4A 7.3	
1.2.2.	Move it to the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
1.2.3.	Position on to the apparatus	P2SSE 19.7 G5	Support the connector group
1.2.4.	Apply pressure	APA 10.6	
1.2.5.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=84.6TMU(0,051min)	
1.3	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
1.3.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.3.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.3.3	Screw the connector on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.3.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

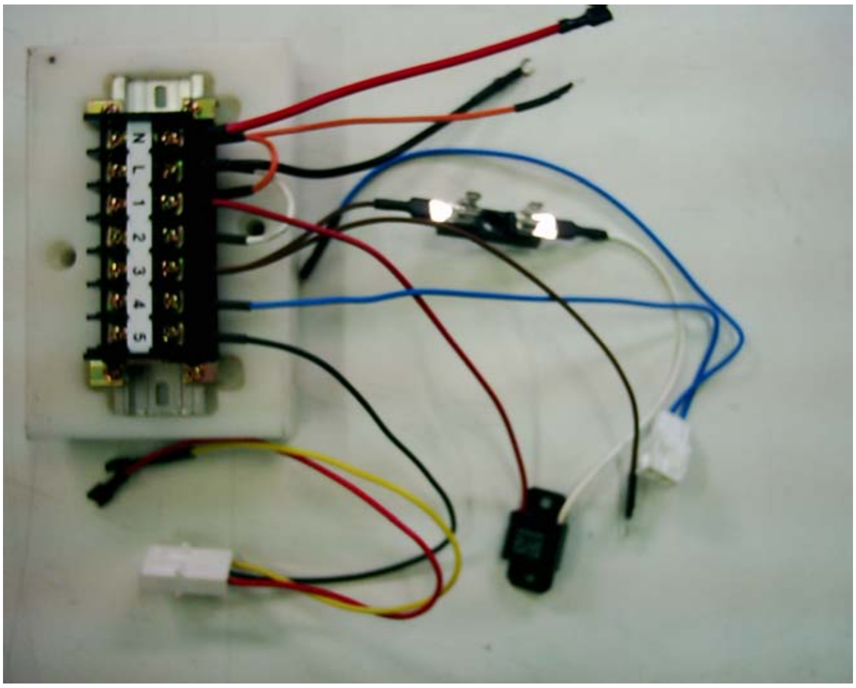


Figure 4.1. Connector Group

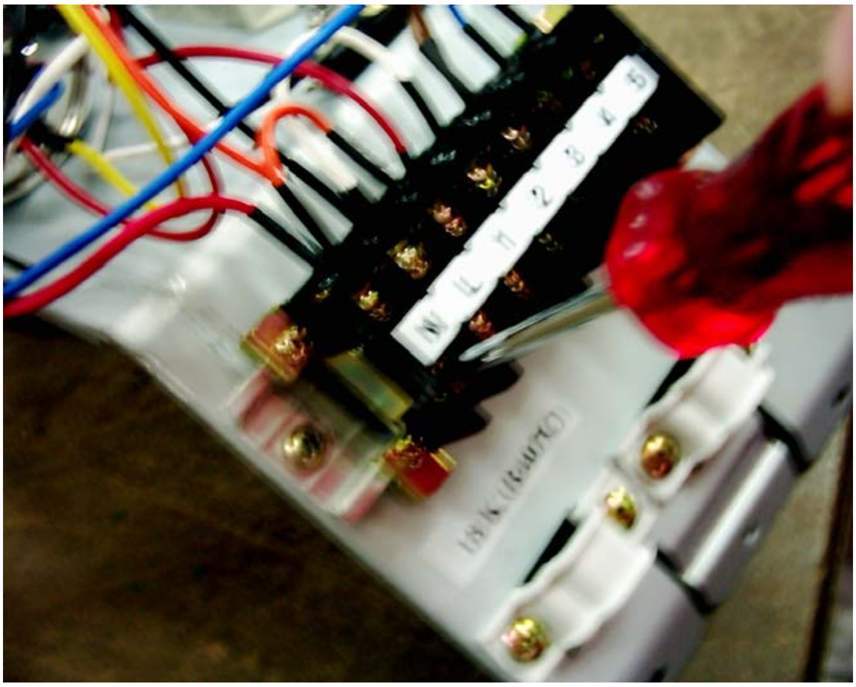


Figure 4.2. Assembling of the Connector Group

Table 4.3. Assembling of holder for an air condition control panels
(Continued Table 4.1)

1.4	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
1.4.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.4.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.4.3	Screw the holder on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.4.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

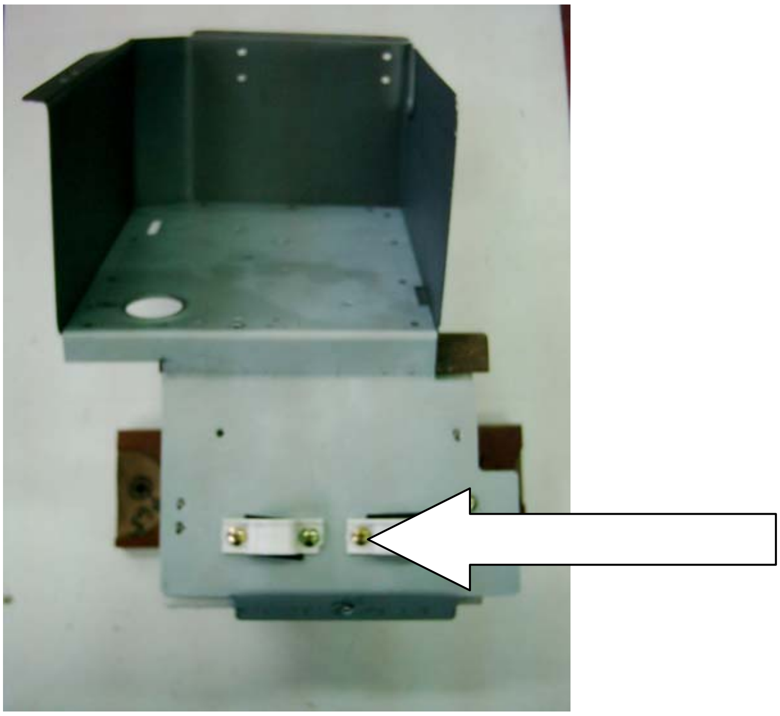


Figure 4.3. Assembling of the holders on to the metal sheet

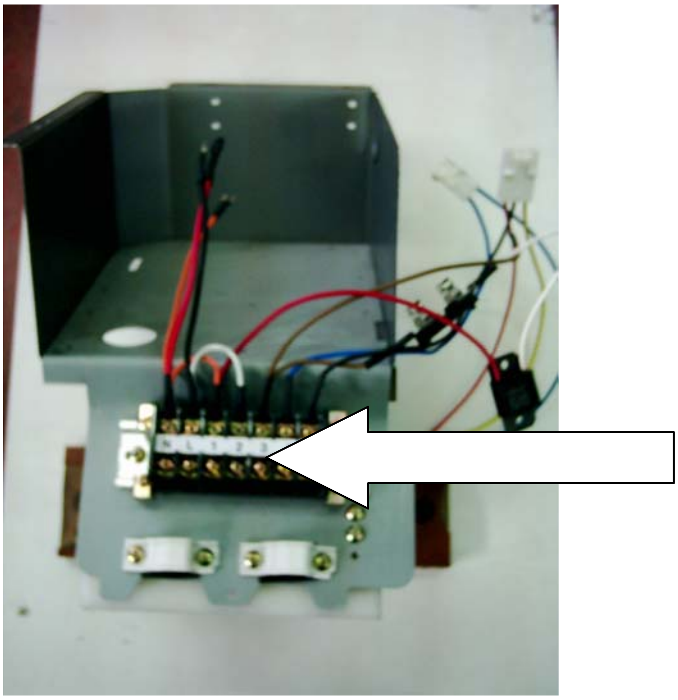


Figure 4.4. Assembling of the connector group and holders on to the metal sheet

Table 4.4. Assembling of sparkiller for an air condition control panels (Continued Table 4.1)

1.5	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
1.5.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.5.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.5.3	Screw the sparkiller on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.5.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

Table 4.5. Assembling of fuse for an air condition control panels (Continued Table 4.1)

1.6	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
1.6.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.6.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.6.3	Screw the fuse on to the metal sheet	PUE15 54 PUE 02 2 GKG 16 PEE05 21 GDK 4	Grasp the screwdriver
1.6.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=175,6 TMU(0,1min)	
1.7	Reach for the group	R35A 10.4	
1.7.1.	Grasp the group	G4A 7.3	
1.7.2.	Move it from the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
1.7.3.	Release on to the conveyor	RL1 2.0 RL1	Release fingers
		Σ=49,2TMU(0,03min)	

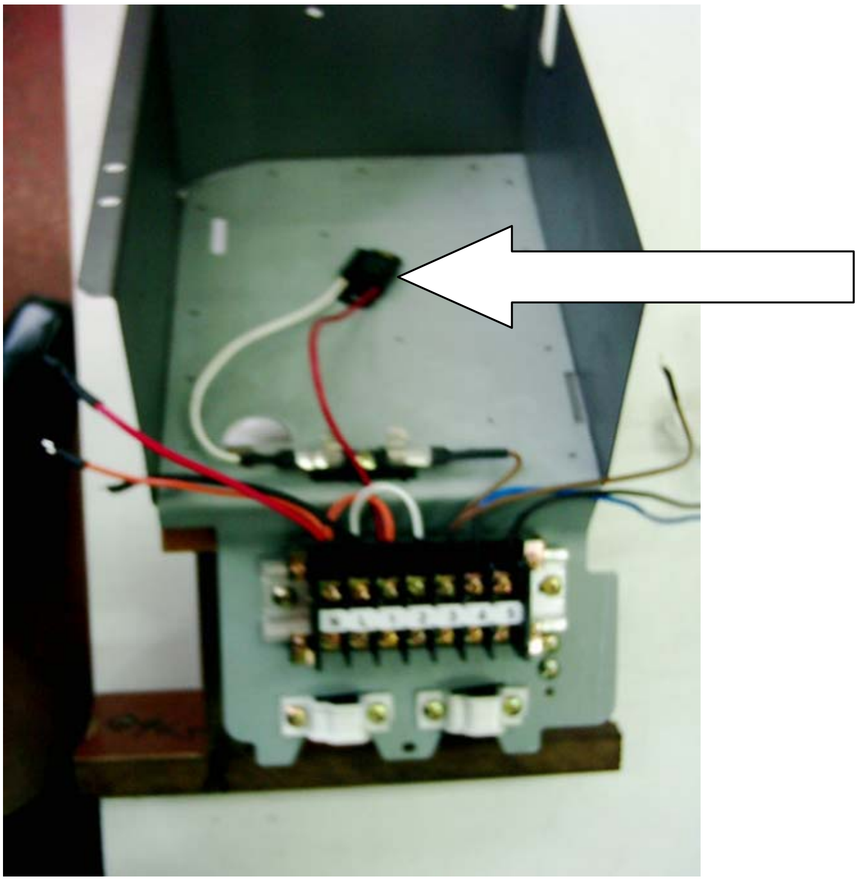


Figure 4.5. Assembling of fuse and sparkiller on to the metal sheet

Table 4.6. Assembling of contactor on to the metal sheet for an air condition control panels (Continued Table 4.1)

2.	ASSEMBLING OF CONTACTOR-METAL SHEET		
2.1.	Take the group and position on to the apparatus		
2.1.1.	Reach for the metal sheet	R35B 14.2	
2.1.2.	Grasp the metal sheet	G4A 7.3	
2.1.3.	Move it to the apparatus	M35A 14.3	
2.1.4.	Eye travel	ET 15.2	
2.1.5.	Position on to the apparatus	P2SD 21,8 G5	Support the metal sheet
2.1.6.	Apply pressure	APA 10.6	
2.1.7.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=85,4 TMU(0,051min)	
2.2	Reach for the contactor	R35C 15.5	
2.2.1.	Grasp the contactor	G4A 7.3	
2.2.2.	Move it to the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
2.2.3.	Position on to the apparatus	P2SSE 19.7 G5	Support the contactor group
2.2.4.	Apply pressure	APA 10.6	
2.2.5.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=84.6TMU(0,051min)	

Table 4.7. Assembling of contactor screw on to the metal sheet for an air condition control panels (Continued Table 4.1)

2.3	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
2.3.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
2.3.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
2.3.3	Screw the contactor on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
2.3.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

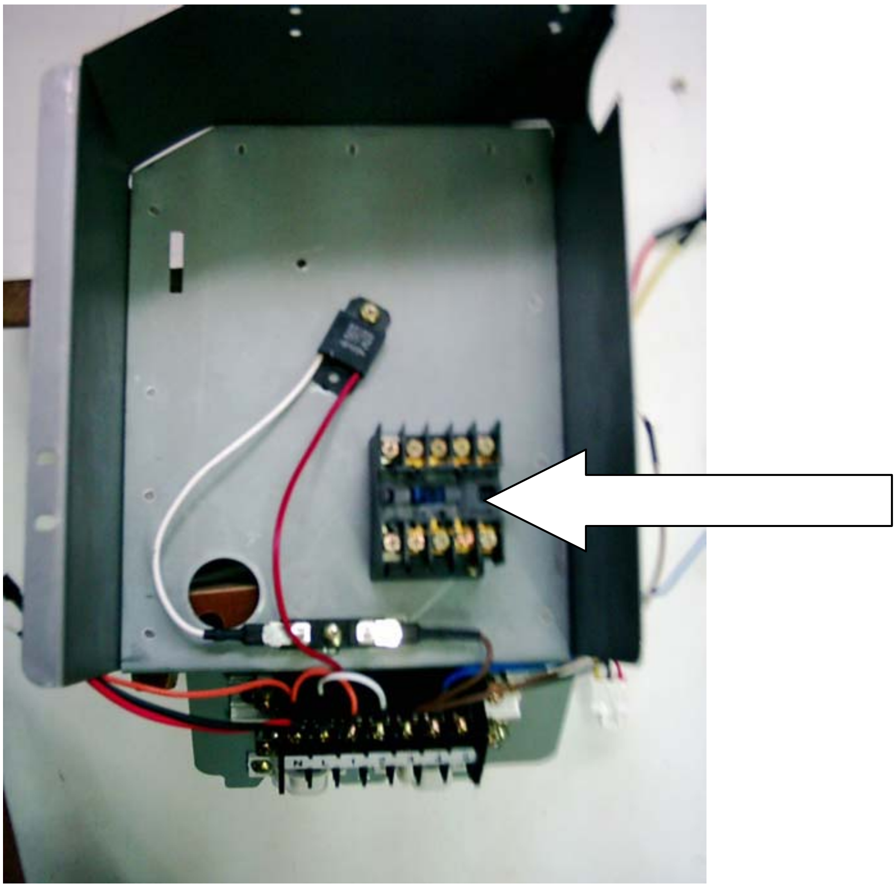


Figure 4.6. Assembling of contactor on to the metal sheet

Table 4.8. Assembling of contactor with the tube group on to the metal sheet for an air condition control panels (Continued Table 4.1)

2.4	Reach for the tube group	R35D 15.5 R35C	
2.4.1.	Through it from the metal sheet	PEE30 31 GKK 11 GKG 16	Grasp the metal sheet
2.4.2	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=75,5 TMU(0,045min)	
2.5	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
2.5.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
2.5.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
2.5.3	Screw the terminals on to the contactor	PUE15 162 PUE 02 6 GKG 48 PEE05 42 GDK 8	Grasp the screwdriver
2.5.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=342,6 TMU(0,20min)	
2.6	Reach for the group	R35A 10.4	
2.6.1.	Grasp the group	G4A 7.3	
2.6.2.	Move it from the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
2.6.3.	Release on to the conveyor	RL1 2.0 RL1	Release fingers
		Σ=49,2TMU(0,03min)	

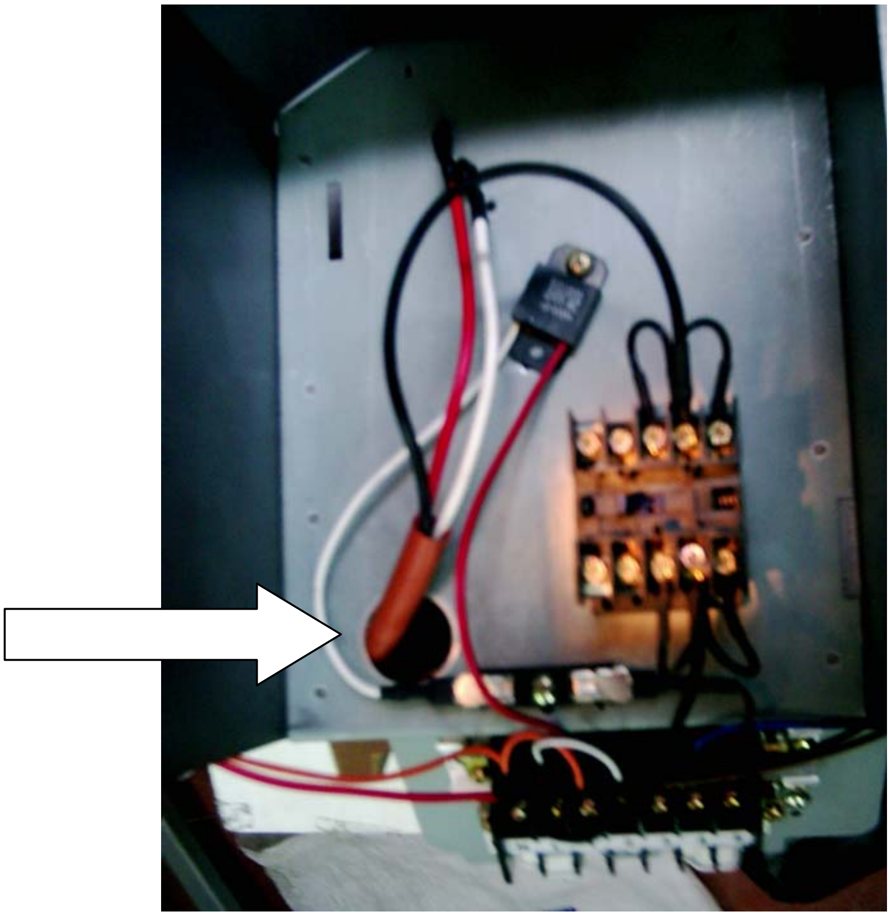


Figure 4.7. Assembling of contactor with the tube group on to the metal sheet

Table 4.9. Assembling of capacitor and the cable for an air condition control panels (Continued Table 4.1)

3.	ASSEMBLING OF CAPACITOR-CABLE		
3.1.	Take the group and position on to the apparatus		
3.1.1.	Reach for the metal sheet	R35B 14.2	
3.1.2.	Grasp the metal sheet	G4A 7.3	
3.1.3.	Move it to the apparatus	M35A 14.3	
3.1.4.	Eye travel	ET 15.2	
3.1.5.	Position on to the apparatus	P2SD 21,8 G5	Support the metal sheet
3.1.6.	Apply pressure	APA 10.6	
3.1.7.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=85,4 TMU(0,051min)	
3.2	Reach for the cable	R35C 124	Reach for the capacitor
3.2.1.	Grasp the cable	G1C3 84,6	
3.2.2.	Move it to the capacitor	M35A 114,4	
	Eye travel	ET 121,6	
3.2.3.	Position on to the capacitor	P3SD 340,2 G5	Support the capacitor group
3.2.4.	Apply pressure	APA 84,8	
3.2.5.	Release fingers	RL1 16.0 RL1	Release fingers
		Σ=887,4 TMU(0,53min)	
3.3	Reach for the group	R35A 10.4	
3.3.1.	Grasp the group	G4A 7.3	
3.3.2.	Move it from the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
3.3.3.	Release on to the conveyor	RL1 2.0 RL1	Release fingers
		Σ=49,2TMU(0,03min)	

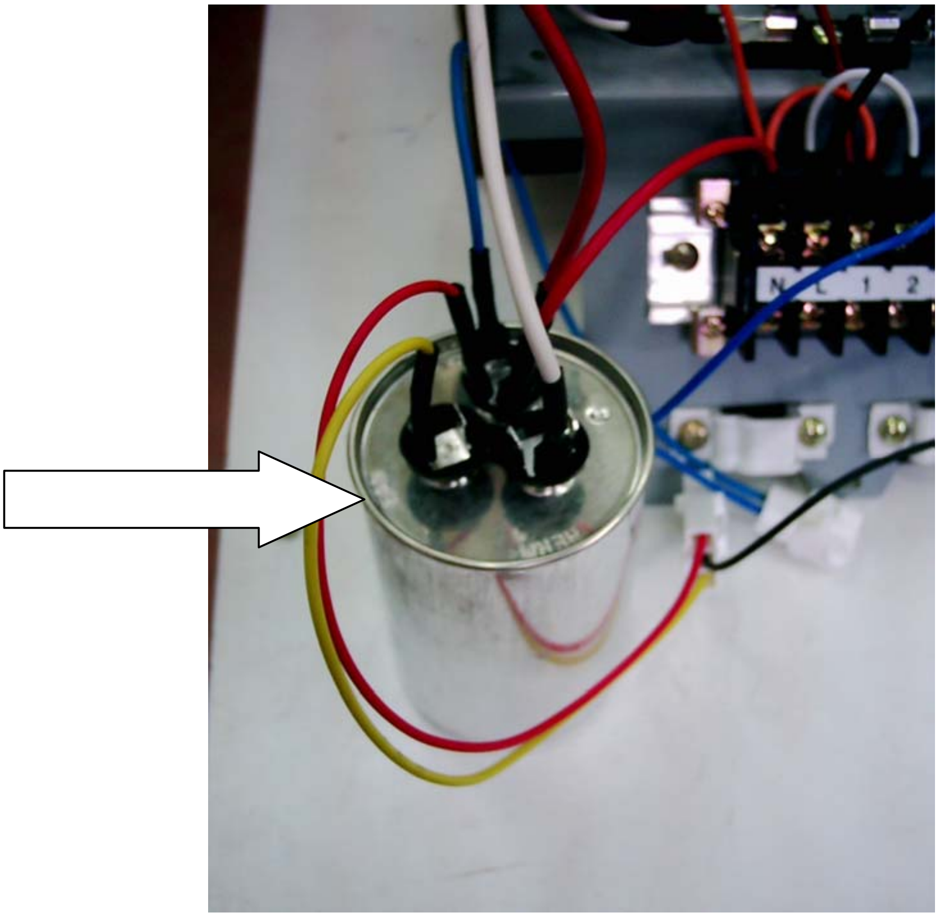


Figure 4.8. Assembling of capacitor and the cable

Table 4.10. Assembling of capacitor for an air condition control panels (Continued Table 4.1)

4.	ASSEMBLING OF CAPACITOR-METAL SHEET		
4.1.	Take the group and position on to the apparatus		
4.1.1.	Reach for the metal sheet	R35B 14.2	
4.1.2.	Grasp the metal sheet	G4A 7.3	
4.1.3.	Move it to the apparatus	M35A 14.3	
4.1.4.	Eye travel	ET 15.2	
4.1.5.	Position on to the apparatus	P2SD 21,8 G5	Support the metal sheet
4.1.6.	Apply pressure	APA 10.6	
4.1.7.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=85,4 TMU(0,051min)	
4.2	Reach for the capacitor&holder	R35C 31	Reach for the capacitor&holder
4.2.1.	Grasp the capacitor&holder	G1C3 21,6	
4.2.2.	Move capacitor&holder on to the metal sheet	M35A 28,6	
	Eye travel	ET 30,4	
4.2.3.	Position on to the capacitor	P3NSD 53,4 G5	Support the capacitor group
4.2.4.	Apply pressure	APA 10,6	
4.2.5	Release fingers	RL1 4.0 RL1	Release fingers
		Σ=179,6 TMU(0,10min)	

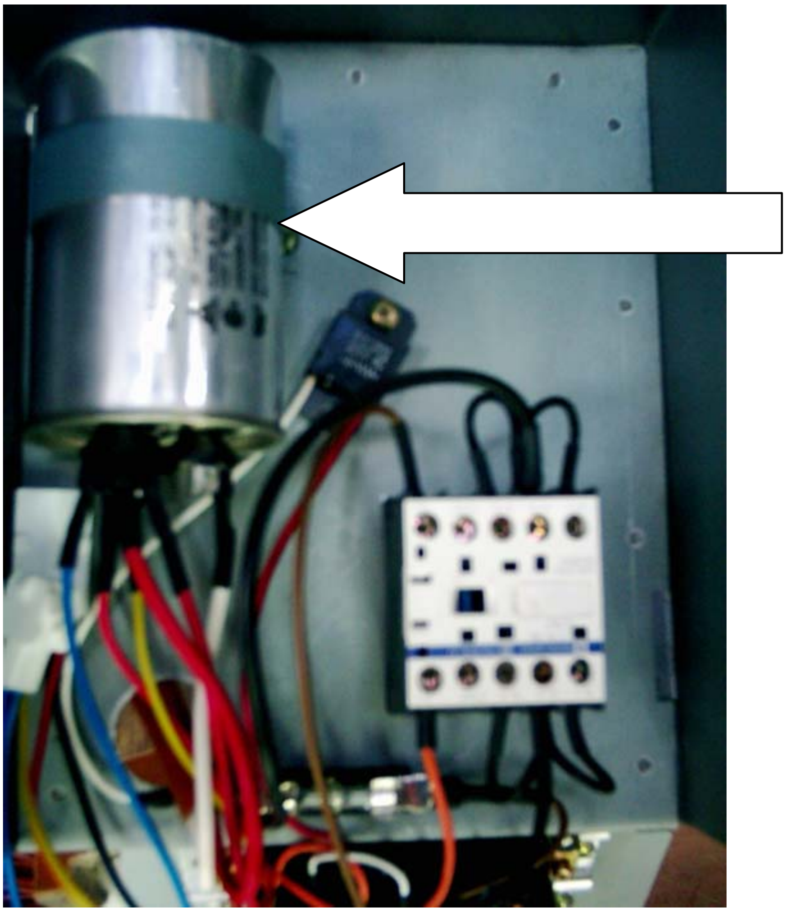


Figure 4.9: Assembling of capacitor on to the metal sheet

Table 4.11. Assembling of capacitor for an air condition control panels (Continued Table 4.1)

4.3	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
4.3.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
4.3.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
4.3.3	Screw the capacitor on to the metal sheet	PUE15 162 PUE 02 6 GKG 48 PEE05 42 GDK 8	Grasp the screwdriver
4.3.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=342,6 TMU(0,20min)	

Table 4.12. Assembling of capacitor for an air condition control panels (Continued Table 4.1)

4.4	Reach for the cable	R35C 15,5	Reach for the capacitor
4.4.1.	Grasp the cable	G1C3 10,8	
4.4.2.	Move it to the capacitor	M35A 14,3	
	Eye travel	ET 15,2	
4.4.3.	Position on to the capacitor	P3SD 48,6 G5	Support the capacitor group
4.4.4.	Apply pressure	APA 10,6	
4.4.5.	Release fingers	RL1 2,0 RL1	Release fingers
		Σ=117 TMU(0,07min)	

Table 4.13. Assembling of capacitor for an air condition control panels (Continued Table 4.1)

4.5	Reach for the cable tie&cut	R35D 31 R35C	
4.5.1.	Through it from the metal sheet&cut	PEE30 62 GKK 22 GKG 32	Grasp the metal sheet
4.5.2	Release fingers	RL1 4 RL1	Release fingers
		Σ=151 TMU(0,09min)	
4.6	Reach for the group	R35A 10.4	
4.6.1.	Grasp the group	G4A 7.3	
4.6.2.	Move it from the apparatus	M35A 14.3	
	Eye travel	ET 15.2	
4.6.3.	Release on to the conveyor	RL1 2.0 RL1	Release fingers
		Σ=49,2TMU(0,03min)	

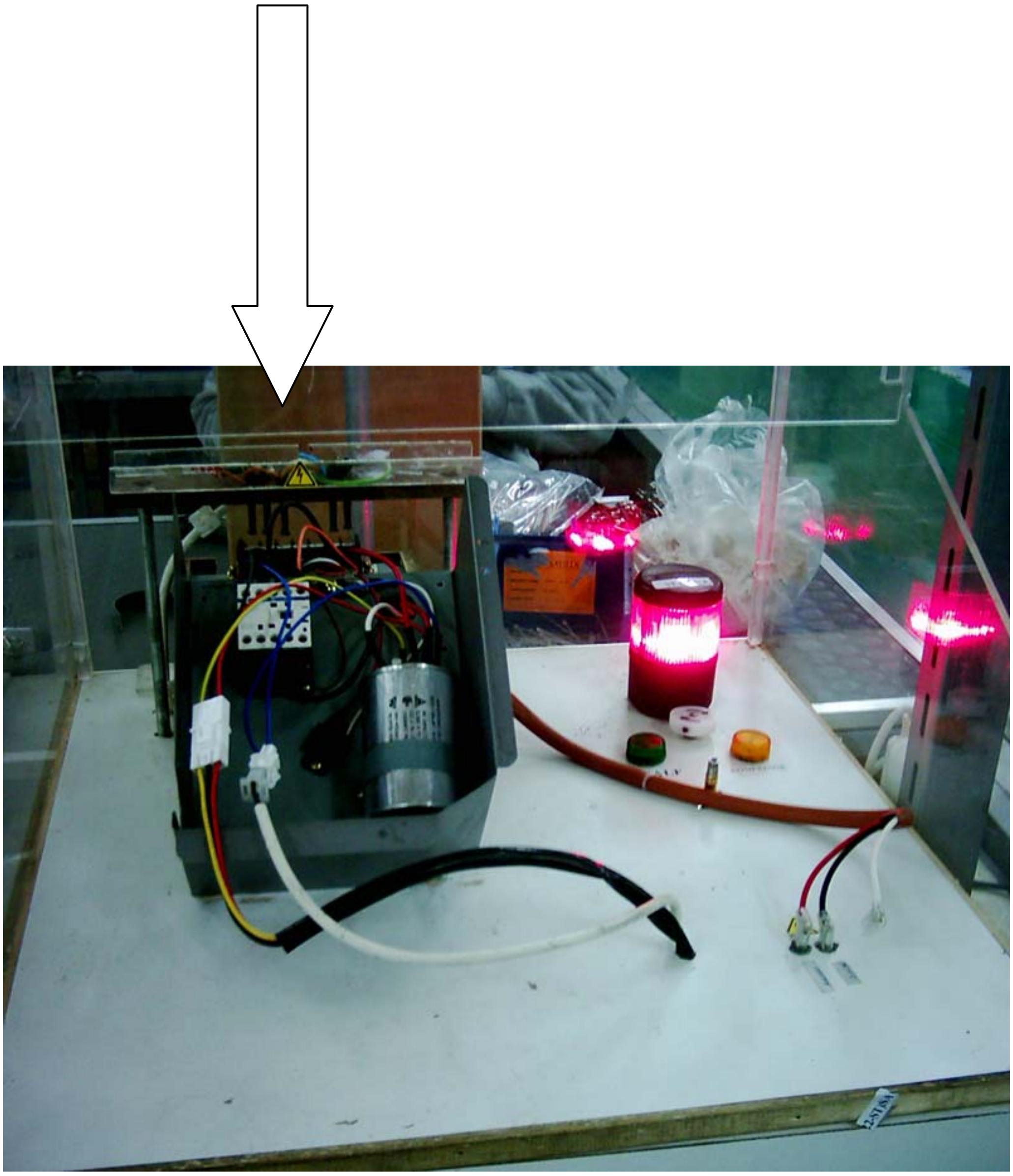


Figure 4.10: Assembling of air condition control panel

4.2. Evaluating the Performance of the Redesigned Assembly Line with the Analysis of Motion Study

Table 4.14. Redesigned assembling of connector, metal sheet, fuse and holder for an air condition control panels

	MTM WORK ANALYSIS		List no:1
Object of manufacture	Operation: AIR CONDITION ASSEMBLY LINE PROCESS		DATE:15/12/2003
Prot. No	Left hand movement description	Symbol TMU Symbol	Right hand movement description
1.	ASSEMBLING OF CONNECTOR-METAL SHEET-FUSE-HOLDER		
1.1.	Take the metal sheet and position on to the apparatus		
1.1.1.	Reach for the metal sheet	R35A 10.4	
1.1.2.	Grasp the metal sheet	G1B 3.5	
1.1.3.	Move it to the apparatus	M35A 14.3	
1.1.4.	Position on to the apparatus	P1SE 5,6 G5	Support the metal sheet
1.1.5.	Apply pressure	APA 10.6	
1.1.6.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=46,4TMU(0,027min)	

Table 4.15. Redesigned assembling of connector group for an air condition control panels (Continued Table 4.14)

1.2	Reach for the connector group	R35A 10.4	
1.2.1.	Grasp the connector group	G1A 2.0	
1.2.2.	Move it to the apparatus	M35A 14.3	
1.2.3.	Position on to the apparatus	P1SE 5.6 G5	Support the connector group
1.2.4.	Apply pressure	APA 10.6	
1.2.5.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=44,9TMU(0,027min)	
1.3	Reach for the screw	R35D 15.5 R30A	Reach for the screwdriver
1.3.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.3.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.3.3	Screw the connector on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.3.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

Table 4.16. Redesigned assembling of holder for an air condition control panels (Continued Table 4.14)

1.4	Reach for the screw	R35D 15.5 R35A	Reach for the screwdriver
1.4.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.4.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.4.3	Screw the holder on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.4.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

Table 4.17. Redesigned assembling of sparkiller for an air condition control panels (Continued Table 4.14)

1.5	Reach for the screw	R35D 15.5 R35A	Reach for the screwdriver
1.5.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.5.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.5.3	Screw the sparkiller on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
1.5.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

Table 4.18. Redesigned assembling of fuse for an air condition control panels (Continued Table 4.14)

1.6	Reach for the screw	R35D 15.5 R35A	Reach for the screwdriver
1.6.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
1.6.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
1.6.3	Screw the fuse on to the metal sheet	PUE15 54 PUE 02 2 GKG 16 PEE05 21 GDK 4	Grasp the screwdriver
1.6.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=175,6 TMU(0,1min)	

Table 4.19. Redesigned assembling of contactor on to the metal sheet for an air condition control panels (Continued Table 4.14)

2.	ASSEMBLING OF CONTACTOR-METAL SHEET		
2.1	Reach for the contactor	R35A 10.4	
2.1.1.	Grasp the contactor	G1A 2.0	
2.1.2.	Move it to the apparatus	M35A 14.3	
2.1.3.	Position on to the apparatus	P1SE 5.6 G5	Support the contactor group
2.1.4.	Apply pressure	APA 10.6	
2.1.5.	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=44,9TMU(0,027min)	
2.2	Reach for the screw	R35D 15.5 R35A	Reach for the screwdriver
2.2.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
2.2.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
2.2.3	Screw the contactor on to the metal sheet	PUE15 108 PUE 02 4 GKG 32 PEE05 21 GDK 4	Grasp the screwdriver
2.2.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=262 TMU(0,135min)	

Table 4.20. Redesigned assembling of tube group on to the metal sheet for an air condition control panels (Continued Table 4.14)

2.3	Reach for the tube group	R35A 10.4 R35A	
2.3.1.	Through it from the metal sheet	PEE30 31 GKK 11 GKG 16	Grasp the metal sheet
2.3.2	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=70,4 TMU(0,042min)	

Table 4.21. Redesigned assembling of contactor on to the metal sheet for an air condition control panels (Continued Table 4.14)

2.4	Reach for the screw	R35D 15.5 R35A	Reach for the screwdriver
2.4.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
2.4.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
2.4.3	Screw the terminals on to the contactor*2	PUE15 162 PUE 02 6 GKG 48 PEE05 42 GDK 8	Grasp the screwdriver
2.4.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=342,6 TMU(0,20min)	

Table 4.22. Redesigned assembling of capacitor and cable group for an air condition control panels (Continued Table 4.14)

3.	ASSEMBLING OF CAPACITOR-CABLE		
3.1	Reach for the cable*8	R30A 76	Reach for the capacitor
3.1.1.	Grasp the cable*8	G1C3 84,6	
3.1.2.	Move it to the capacitor*8	M35A 114,4	
3.1.3.	Position on to the capacitor*8	P3SD 340,2 G5	Support the capacitor group
3.1.4.	Apply pressure*8	APA 84,8	
3.1.5.	Release fingers*8	RL1 16.0 RL1	Release fingers
		Σ=716TMU(0,43min)	

Table 4.23. Redesigned assembling of capacitor and metal sheet for an air condition control panels (Continued Table 4.14)

4.	ASSEMBLING OF CAPACITOR-METAL SHEET		
4.1	Reach for the capacitor&holder*2	R35C 31	Reach for the capacitor&holder
4.1.1.	Grasp the capacitor&holder*2	G1C3 21,6	
4.1.2.	Move capacitor&holder on to the metal sheet*2	M35A 28,6	
4.1.3.	Position on to the capacitor	P3NSE 47,8 G5	Support the capacitor group
4.1.4.	Apply pressure	APA 10,6	
4.1.5	Release fingers	RL1 4.0 RL1	Release fingers
		Σ=143,6TMU(0,08min)	
4.2	Reach for the screw	R35D 15.5 R35C	Reach for the screwdriver
4.2.1.	Grasp the screw, change of the screw way	G1B 3.5 G1A G2 5.6	Grasp the screwdriver
4.2.2.	Move it to the screwdriver	ALE30 17 PAE15 15 PEE15 26 GDK 4	Grasp the screwdriver
4.2.3	Screw the capacitor on to the metal sheet	PUE15 162 PUE 02 6 GKG 48 PEE05 42 GDK 8	Grasp the screwdriver
4.2.4	Release fingers	RL1 2.0 RL1	Release fingers
		Σ=342,6 TMU(0,20min)	

Table 4.24. Redesigned assembling of capacitor and cable for an air condition control panels (Continued Table 4.14)

4.3	Reach for the cable	R35A 10,4	Reach for the capacitor
4.3.1.	Grasp the cable	G1C3 10,8	
4.3.2.	Move it to the capacitor	M35A 14,3	
4.3.3.	Position on to the capacitor	P3SE 43.0 G5	Support the capacitor group
4.3.4.	Apply pressure	APA 10,6	
4.3.5.	Release fingers	RL1 2,0 RL1	Release fingers
		Σ=91,2 TMU(0,054min)	

Table 4.25. Redesigned assembling of cable for an air condition control panels (Continued Table 4.14)

4.4	Reach for the cable tie&cut*2	R35D 31 R35C	
4.4.1.	Through it from the metal sheet&cut*2	PEE30 62 GKK 22 GKG 32	Grasp the metal sheet
4.4.2	Release fingers*2	RL1 4 RL1	Release fingers
		Σ=151 TMU(0,09min)	

Figure 4.11. Assembling of ex air condition control panel

Figure 4.12. Assembling of redesigned air condition control panel

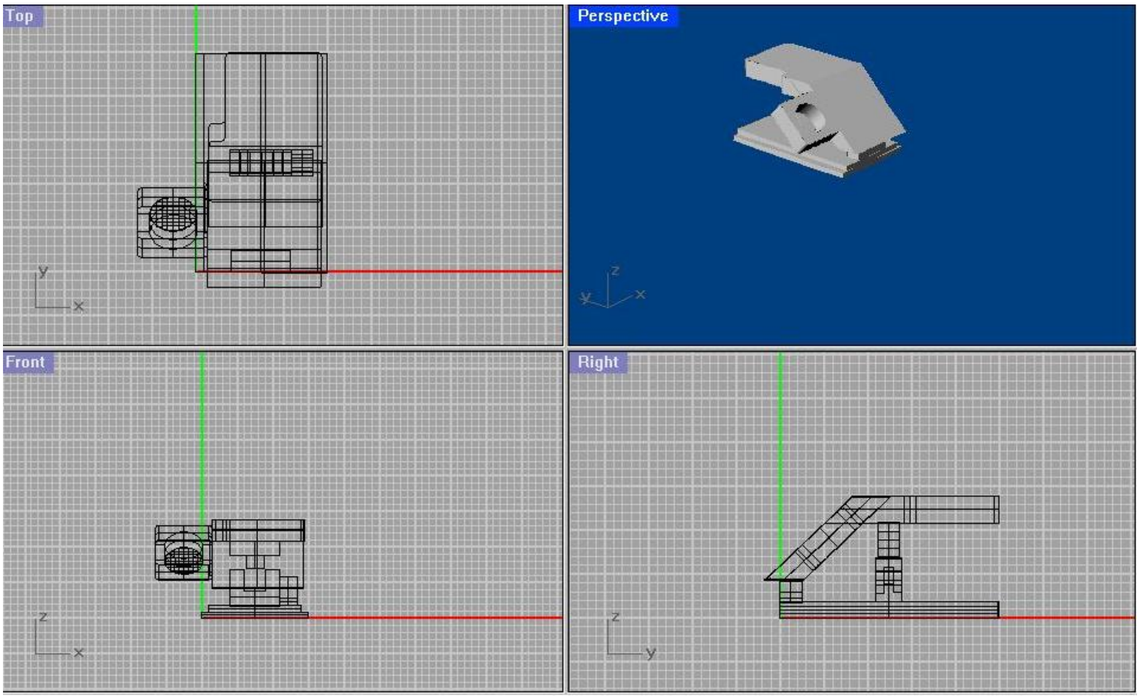


Figure 4.13. Technical view of apparatus of redesigned air condition control panel

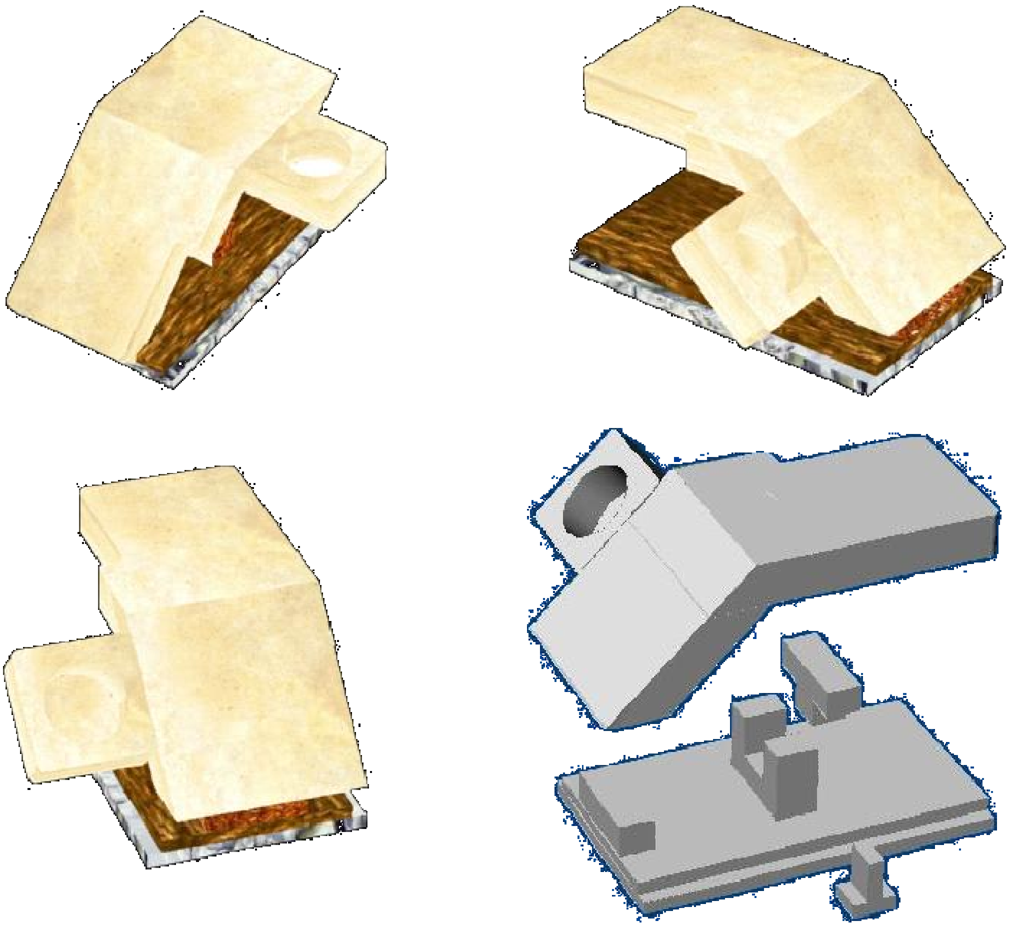


Figure 4.14. Apparatus of redesigned air condition control panel

Table 4.26. Comparison of Ex Assembly Line and Redesigned Assembly Line (TMU)

Operational Sections	Ex Assembly Line (TMU)	Redesigned Assembly Line (TMU)
Assembling of connector-metal sheet-fuse-holder	1180,8	1052,9
Assembling of contactor- metal sheet	899,3	719,9
Assembling of capacitor-cable	1022	716
Assembling of capacitor- metal sheet	924,8	728,4
Total (TMU)	4026,9	3217,2
Total (MIN)	2,41	1,93
Saving time		%20

4.3. Definition of Symbols Used in Tables

R XX A (D):
R: REACH
XX: DISTANCE MOVED (cm)
A: REACH TYPE (Reach to an object in fixed location)
D: REACH TYPE (Reach to a very small object or where accurate grasp is required)

G X Y Z:
G: GRASP
G1A: Pick up Grasp: Small, medium or large object by itself, easily grasped.
G1B: Very small object or object lying close against a flat surface
G5: Contact, sliding or hook grasp

P: POSITION
P1SE: Positioning with no pressure required to a symmetric object which easy to handle

RL: RELEASE
RL1: Normal release performed by opening fingers as independent motion.

APA: APPLY PRESSURE

M XX A:
M: MOVE
XX: DISTANCE MOVED (cm)
A: MOVING TYPE (Move object to other hand against stop)

ALE (XX):
ALE: Take an object with easy way
XX: DISTANCE MOVED (cm)

PAE (XX):

PAE: Position an object near by the other hand

PEE: Position an object for narrow place

XX: DISTANCE MOVED (cm)

PUE (XX):

PUE: Positioning an object which location is uncertain.

XX: DISTANCE MOVED (cm)

GKG: Apply force on an object

GDK: Turned an object with an angle

At the end of this study we see that eliminating unnecessary operations we can save %20 percentages time of production. In this study we take away unnecessary transportation of the goods. This means that before the study we were produce 600 pcs material but after the study we calculate that we can produce 720 pcs with four people in one ship.

Due to today’s companies competitive price is the most important thing for surviving in the field. Material cost is the almost same with the most companies so the importance of labor cost is appear in that position it is determine the good price.

%20 percentages time saving from the cycle of the goods means that reducing the labor cost % 20 percentage. Because of the lower unit cost the market and/or profit potential of the firm will increase.

CHAPTER 5

CONCLUSION

‘Manufacturing design for productivity’ have been discussed and evaluated by a case study of an assembly line for air conditioning control panels throughout this thesis. The specific objective of this study is to investigate the relationship between manufacturing design and productivity issues. To accomplish the above mentioned objective of the study, firstly the use of methods engineering in the factory system is explained, then the relationships between analytical techniques of methods engineering are discussed. Afterwards the state-of-the-art systems used in methods engineering are explained in some sectors. Later on, an assembly line is selected as the case study. An ex-assembly is redesigned by using the concepts of methods engineering. Then both cases (i.e., ex-assembly line and redesigned assembly line) are analyzed and discussed in terms of their output capacity and manufacturing time.

In the process of analyzing ex-assembly line operations, first we identify unnecessary motions and decide to calculate how much time we could save if we had redesigned the production line. Since there is a no redesigned assembly that we can us for measurements, we used methods time measurement (MTM) analysis. Using by MTM analysis we could measure the effectiveness of the project.

Redesigned assembly line has designed by principles of motion economy that both hands worked at the same time, the hands worked in opposite symmetrical directions, each hand gone through as few motions as possible, the work place has designed to avoid long reaches and we have avoid using the hand as a holding device.

After the analysis of MTM for redesigned assembly line it is observed that we can reduce production cycle time 20 % at the end of this study. And this development project has been chosen for investment. We increased the production quantity from 600 pcs. to 800 pcs. with four people in one shift. Because efficiency of workers have increased with the redesigned assembly line, production of the goods of quantity increased 13 % more than originally calculated.

The main differences between ex-assembly line and redesigned assembly line are:

- The ex-assembly line was consist of four table and one assembly line between them. The ex-assembly line was covering 13,5m² square but new-assembly line consist of just a line apparatus on it and it covers 3,6 m².
- The ex-assembly line was consist of the apparatus on the tables but they could be moved by force of operator while assembling. The new apparatus is stable on the redesigned assembly line and they can not be moved by force of the operator.
- The operators could wait while assembling their parts, because they take the part from the line to assembly on their table and they can do whenever they want. Because of the one operator, the other operators might wait. However, redesigned line does not allow operator to wait while assembling because it moves in front of the operators and apparatus on the line, when the product come in front of the operator, the product have to be assembled by the operators.
- In the ex-assembly line operators sit on the chairs and work on the tables, they have to move a long distance. On the other hand, operators do not move that much for the redesigned line.
- Analyzing the method of MTM analysis we could foresee the results of this study. 20 % increase in productivity can be observed. Time study analysis is used for redesigned assembly line for operational time balance.
- Because of efficiency and productivity increase of this study that we mentioned above, totally we observed 33 % production increase for the same period of time.
- By the standardization and the elimination of the operations, and reducing the labor cost the factory could increase its competitive strength.

5.1. Concluding Remarks and Recommendations for Future Studies

Throughout this study, an ex-assembly line is analyzed and redesigned for productivity. The main aim is to investigate the possibilities of operational improvement on the production time in a cost-effective manner. During this study, the most important restriction is the constraint that we can not redesign the product but we can only redesign production line.

In the field we see that most effective ways are full automatic production lines that work with full automatic robots. Designing a full automatic assembly line we can observe %100 productivity from the line compared to the operators.

However the cost of such automation is currently very high. Therefore this study is showing the cost-effective way of increasing productivity of an existing assembly line by redesigning it.

Future studies can be conducted on the issue by considering test systems and measuring systems.

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