CERTIFICATION OF APPROVAL

Modeling of Assembly Line of Finder Unit for Camera

by

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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

The Dissertation consists of six main divisions excluding Abstract and Appendix. The main divisions are Introduction, Literature Review & Theory, Methodology, Results & Discussion, Conclusion and References. The study was carried out to model the assembly line of finder unit of camera by using WITNESS software. It was also to perform sensitivity analysis in order to propose the best layout, besides, to be familiar with WITNESS software by using its basic and advanced features. Three main measurements were highly evaluated; production rate, throughput time and number of WIP. The study scope was on particular assembly line of the finder unit. It was a component in a camera used to look through when the camera was in hand-to-view position. Simulation role was to evaluate alternatives to support strategic initiatives or support better performance at operational and tactical levels.

The following were studied in supporting the project;

(a) Manufacturing System, (b) Facility Layout, (c) Manual Assembly Line, (d)Automated Assembly Line, (e) Single Station, (f) Time Study, (g) WITNESS software.

There were three types of layouts proposed in the project; in-line manual assembly line, in-line semi-automated assembly line and single station. The method involved during the simulation were introducing the elements, entering the input and output rules, editing the details of the elements, running the simulation, obtaining the reports and analysis. The main tools used were WITNESS software and stopwatch. Based on the simulation it was found that overall, the setting station was the busiest station for almost all designs compared to other stations. Some of the stations also acquired idle and blocked percentages. The best production rate was produced by Design 1 with additional number of setting station, 27.1 units/hr whereas the throughput time was 2.22 minutes. However, the number of WIP was very high that was 78 units. In conclusion, the modeling of assembling lines was successfully performed within the allocated time. The use of the WITNESS software in the project helped much in modeling and sensitivity analysis. It was recommended for continuation to include more advanced and attractive display features, and improve the current system in term of increasing the production rate and reducing the WIP.

ACKNOWLEDGMENT

In the name of Allah, The Most Gracious, The Most Merciful. First and foremost, I thank to Allah , as with His blessings I was able to complete my final year project.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study.

Recently, there have been many innovations and development with regards to the assembly technology in order to meet the manufacturing requirement and future development. The development of electronic controls enables industry to introduce the automation system in order to produce products by mechanical power with minimum of human control. This developing technology has been utilized to the vast of manufacturing applications for the efficient operation and production.

In general, manufacturing system could be defined as a collection of integrated equipment and human resources, whose function is to perform one or more processing and/or assembly operation on a starting raw material, part, or set of parts. The integrated equipment includes production machines and tools, material handling and work positioning devices, and computer systems.

The title of the project is "Modeling of Assembly Line of Finder Unit for Camera". The project is related with the assembly line of finder unit for camera. Generally, finder unit is one of the components in a camera. It consists of two part; finder base plate and eyepiece lens. It plays an important role in a particular camera, which is used to look through when the camera is in hand-to-view position. In a particular camera, it is normally located almost at the top part. The Figure 1.1 shows the example of a model of a camera produced by a company.

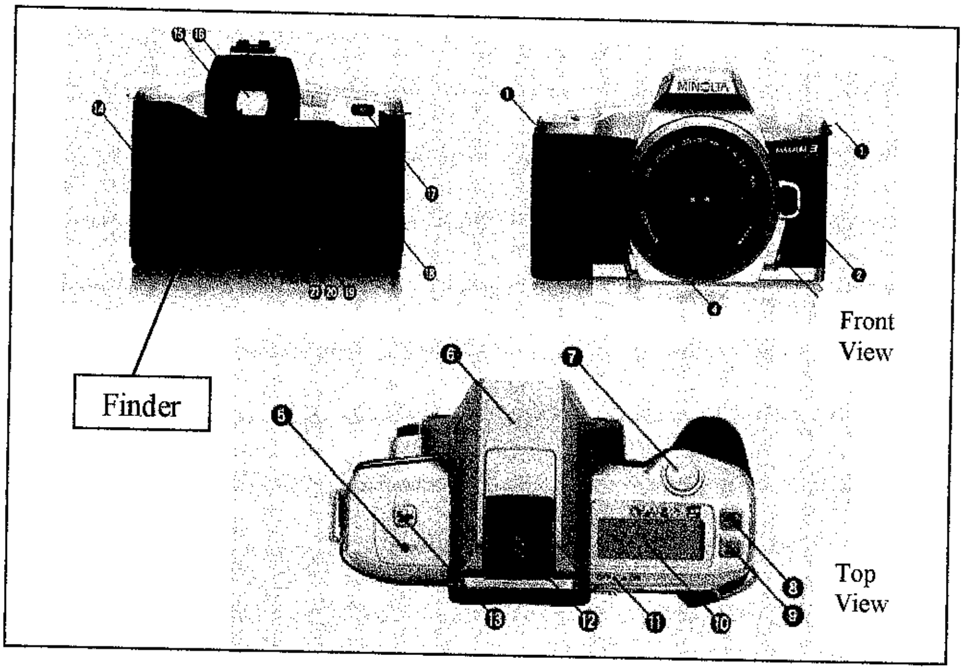

Figure 1.1 : The location of a finder unit in a camera.

On the other hand, there are some other components to be processed in order to produce a complete camera such as lenses, film window, back-cover release, select button, data button, etc. Each of the components has its particular type of assembly line. Please refer to the Appendix 3 for the system chart of a camera.

In general, the project introduced the use of WITNESS software. WITNESS software is an interactive simulation program, which has discrete and continuous simulation models. This stochastic and deterministic program able to support incremental development of models with graphical display of model behavior. The models also can be altered during running.

The role of simulation is to evaluate alternatives that either support strategic initiatives, or support better performance at operational and tactical levels. Simulation provides the information needed to make these types of decisions. The simulation approach supports multiple analyses by allowing rapid changes to a model's logic and data and is capable of handling large, complex system such as manufacturing facility.

Using the simulation to visualize the system under investigation could increase the credibility of a project. A greater understanding of the system being studied also could be gained by using simulation. Moreover, the benefit to be gained through simulation modeling is to lower the cost, since the particular facility design could be simulated instead of performing the real trial and error manufacturing practices. Furthermore, it is also acquires the ability to try many options quickly and easily.

1.2 Problem Statement

The design of assembly lines for production operation is deemed crucial, especially in ensuring the optimal productivity and minimal work-in-process. Both are significant in order to achieve efficient production. A case study that involves layout designing, simulation work and sensitivity analysis on an assembly line of an example of a real manufacturing process is to be considered in the project.

1.3 Objectives

The objectives of the project are;

1. To model the assembly line of finder unit of camera by using WITNESS software.
2. To propose several layouts in order to perform sensitivity analysis with the aim of proposing the best layout.
3. To be familiar with WITNESS software by using its basic and advanced features.

1.4 Scope of Study

The scope of the study is on particular assembly line for the production of finder unit. It was not included the whole processes in producing a camera. The scope in using the WITNESS software included the basic and advanced features. During the analysis, the cost scope was not taken into consideration.

CHAPTER 2

LITERATURE REVIEW & THEORY

2.1 Manufacturing System

Manufacturing can be defined as the application of physical and chemical processes to alter the geometry, properties, and appearance of a given starting material to make parts or products.[8]

Manufacturing also includes the joining of multiple parts to make assembled products. The processes that accomplish manufacturing involve a combination of machinery, tools, power and manual labor. Manufacturing is almost always carried out as a sequence of operations.

Based on the economic viewpoint, manufacturing if referring to the transformation of materials into items of greater value by means of one or more processing or assembly operations. The key point is that manufacturing adds value to the material by changing its shape or properties or by combining it with other materials that have been similarly altered. The material has been made more valuable through the manufacturing operation performed on it.

There are four main activities in manufacturing.; (1) processing and assembly operations, (2) material handling, (3) inspection and test, and (4) coordination and control. A *processing operation* transforms a work material from one state of completion to a more advanced state that is closer to the final desired part or product, whereas an *assembly operation* joins two or more components to create a new entity, which is called an assembly, subassembly or some other term that refers to specific joining process.

In most manufacturing plants, materials spent more time being moved and stored than being processed. In some cases, the majority of the labor cost in the factory is consumed in handling, moving and storing materials. It is important that this function be carried out as efficiently as possible.

Eugene Merchant, an advocate and spokesman for the machine tool industry for many years, observed that materials in a typical metal machining batch factory or job shop spend more time waiting or being moved than in processing [5] Inspection and test are quality control activities. The purpose of the inspection is to determine whether the manufactured product meets the established design standards and specifications. The coordination and control in manufacturing includes both the regulations of individual processing and assembly operations as well as the management of plant level activities. Control at the process level involves the achievement of certain performance objectives by properly manipulating the inputs and other parameters of the process. Control at the plant level includes effective use of labor, maintenance of the equipment, moving materials in the factory, controlling inventory, and keeping plant operating costs at a minimum possible level.

2.2 Facility Layout

In a manufacturing system, the term facilities includes machines, workstations, inspection stations, washing stations, locker rooms, rest areas and other such support facilities [1]. It is typically to make a tangible product or provide a service.

According to Sunderesh Heragu from Renselaer Polytechnic Institute, the facility must be properly managed to achieve its stated purpose while satisfying several objectives. In order to manage the facilities, one must understand the underlying decision problems faced in such systems. There are some important design questions that need to be addressed in managing those facilities such as the preliminary process plan development, layout of manufacturing cells and machines, etc. Solving manufacturing cell determination and cell layout problems is generally required for only manufacturing systems that produce a large number of components and for which manufacturing activities can be divided into almost mutually independent cells.

The term layout can be defined as the configuration of department, work centers and equipment with particular emphasis on movement of work (customers or materials) through the system.

The importance of the layout decisions is it requires substantial investment of money and effort. Besides, it involves long-term commitments. However, it also has significant impact on cost and efficiency of short-term operation.

In creating the layouts, there are several data, which could assist the process. One of the essential data is the frequency of trips or flow of material or some other measure of interaction between facilities. If the data is not available, the facilities designer must at least have subjective information about the flow intensities between facilities. The other data is shape and size of facilities. Besides, it is also important to know the available floor space and the adjacency requirements between pairs of facilities.

There are three types of basic layouts; (1) Process layout, (2) Product layout (assembly line) and (3) Cellular manufacturing. In general, the production resources of *process layout* are arranged by common processes. This layout is often used to produce or process a large variety of non-standardized products in relatively small batches. As for the *product layout*, the production resources are arranged by the production sequence of products. This layout is common to produce or process a limited number of standardized products with direct material flow. *The Cellular Manufacturing* or *Group Technology* layout is to allocate dissimilar machines into cells to work on products having similar processing requirement. *The Cellular Manufacturing* layout is designed to gain the benefits of product layout in job-shop kind of production.

It is important to determine the best type of layout to avoid complicated problem in the future. The incorrect decision in determining the layout could be very costly. The attempt to adapt with the inappropriate layout would require money for some expenses.

2.3 Manual Assembly Line.

Manual assembly line is a production line that consists of a sequence of workstations where assembly tasks are performed by human workers.

There are several factors that contribute to the need of using manual assembly line. One of the factors is when the demand for the product is high or medium. The other factor is when the products made on the line are identical or similar. It is also significant when the total work required to assemble the product can be divided into small work elements. The last factor is when the technologically impossible of economically infeasible to automate the assembly operations.

Manual assembly line technology has made a significant contribution to the development of American industry in the twentieth century. It remains an important production system throughout the world in the manufacture of automobiles, consumer appliances, and other assembled products, which made in large quantities.

A workstation of a manual assembly line is a designated location along the work flow path at which one or more work elements are performed by one or more workers. The work elements represent small portions of the total work that must be accomplished to assemble the product. Some workstations are designed for workers to stand, while others allow to sit. When the workers stand, they can move about the station area to perform their assigned task. This is common for assembly of large products, such as cars and trucks. The typical case is when the product is moved by a conveyor at constant velocity through the station. The worker begins the assembly task near the upstream side of the station and moves along with the work unit until the task is completed, then walks back to the next work unit and repeats the cycle.

For smaller assembled products, the workstations are usually designed to allow the workers to sit while they perform their task. This is more comfortable and less fatiguing for the workers and is generally more conducive to precision and accuracy in the assembly task. The example of the product such as electronic devices, small appliances, and subassemblies used on larger products.

2.4 Automated Assembly Line.

The term automated refers to the use of mechanized and automated devices to perform the various assembly tasks in an assembly line or cell.

The application of automated assembly line is most appropriate where there is high product demand. The use of this system is able to fulfil the requirement of high product quantities. It is also suitable for stable product design because frequent design changes are difficult to cope with an automated production line. It is also appropriates for long product life for at least several years in most cases and for multiple operations which are performed on the product during its manufacture.

In a particular automated assembly line, there are multiple workstations that are linked together by a work handling system that transfers parts from one station to the next station. A raw workpart enters one end of the line and the processing steps are performed sequentially as the part progresses forward. An automated production line operates in cycles. Each cycle consists of processing time plus the time to transfer parts to their respective next workstations. The slowest workstation on the line sets the pace of the line, just as in an assembly line.

There are three main types of workflow in automated assembly line; (1) in-line, (2) segmented and (3) rotary. The in-line configuration consists of a sequence of stations in a straight-line arrangement. This configuration is commonly used for machining big workpieces, such as automotive engine blocks and engine heads. A production line with many stations is required to perform a large number of operations. This type of configuration could accommodate a large number of stations. In could also be designed with integrated storage buffers along the flow path.

The second classification of the configuration is the segmented in-line that consists of two or more straight-line transfer sections where the segments are usually perpendicular to each other. It is usually used due to the availability of floor space, which sometime may limit the length of the line. In the rotary configuration, the workparts are attached to fixtures around the periphery of a circular worktable, and the table is indexed to present the parts to workstations for processing. Rotary indexing systems are commonly limited to smaller workparts and fewer workstations compared to in-line and segmented in-line configurations.

There are several benefits could be provided by this system. One of them is lowering direct labor content, since the automated system could perform the task independently, except for setup and maintenance. It is also reducing the product cost because cost of fixed equipment is spread over many units. Furthermore, it could increase the production rates and minimize the production lead time and work-in-process.

2.5 Single-station.

In general, single station manufacturing cell exists in two forms; single station manned cell and single station automated cell.

A single station manual assembly cell consists of single workplaces in which the assembly work is accomplished on the product or some major subassembly of the product. This method is usually used on products that are complex and produced in small quantities. The workstation may require one or more workers, depending on the size of the product and the required production rate.

There are several reasons of utilizing this type of layout. One of the reasons is due to its shortest amount of time to implement. As a result, the user company can quickly launch production of a new part or product, while it plans and designs a more automated production method. It requires the least capital investment of all manufacturing systems. Technologically, it is the easiest system to install and operate since only one machine is involves during the operation. Furthermore, it is the most flexible manufacturing system with regard to changeovers from one part or product style to the next.

The machine is usually being operated manually or semi-automated. In a manual operated station, the operator controls the machine and loads and unloads the work. The work cycle requires the attention of the worker either continuously or for most of the cycle. For instance, the operator might relax temporarily during the cycle when the machine feed is engaged on the lathe or drill press. An assembly example is a worker assembling components to a one-of-a-kind printed circuit board in an electronics plant. The task requires the constant attention of the worker. Some manually operated stations also includes the task that needs the use of hand tools like screwdriver or portable powered tools such as arc welding gun, soldering iron and powered hand-held drill.

The single station system is slower since all of the assembly tasks are performed and only one assembled unit is completed each cycle.

2.6 Time Study

Time study involves the technique of establishing an allowed time standard to perform a given task, based on measurement of the work content of the prescribed method, with allowance for fatigue and for personal and unavoidable delays.[3] It is often referred to as work measurement.

There are several techniques used by the time study analysts with the aim of establishing a standard, such as a computerized data collection, a stopwatch study, standard data, fundamental motion data, work sampling and estimates based on historical data. Each of the technique has application under certain conditions.

Nowadays, in order to position a firm as a world class competitor, the implementation of performance measurement systems to meet the demands of just-in-time quality control and time-compressed management. In order to facilitate performance, every craftsperson uses tool. This is to ease the process of performing job in a shorter time. According to Benjamin W Niebel, the Professor Emeritus of Industrial Engineering of The Pennsylvania State University, there are eight different process charts introduced with specific application; (1) The Operation Process Chart, (2) The Flow Process Chart, (3) The Flow Diagram, (4) The Worker & Machine Process Chart, (5) The Gang Process Chart, (6) The Operator Process Chart, (7) The Travel Chart, and (8) The PERT Chart. By using these process charts, the time usage can be predicted, planned and managed.

2.7 WITNESS software

The special feature about this software is it has the capability to show what the hidden process and the overall processes, which are occurring within the plant or factory, which is impossible to be observed simultaneously in the real plant.

There are two main physical elements in Witness software; (1) discrete and (2) continuous. The discrete elements comprise of parts, buffers, machines, conveyors, vehicles or trucks and labor. On the other hand, the continuous elements consist of fluids, tanks, processors, and pipes.

The WITNESS environment is found very user friendly. There are various components in WITNESS software. The main components are the Menus, Element Selector, Toolbars, Status Bar, Dialogs and Dialogs Pages, Visual Rules dialogs, Windows, Layers, WITNESS Rules and Function Editor, Interact Box, Clock, and Help Facility.

Each line in the Menu is a command. There are nine different WITNESS menus are available; File, Edit, View, Model, Elements, Reports, Run , Window and Help. The Element Selector displays a hierarchical view of the elements in the model. This would allow the user to keep an overview of the structure of the structure of the model and to control it easily.

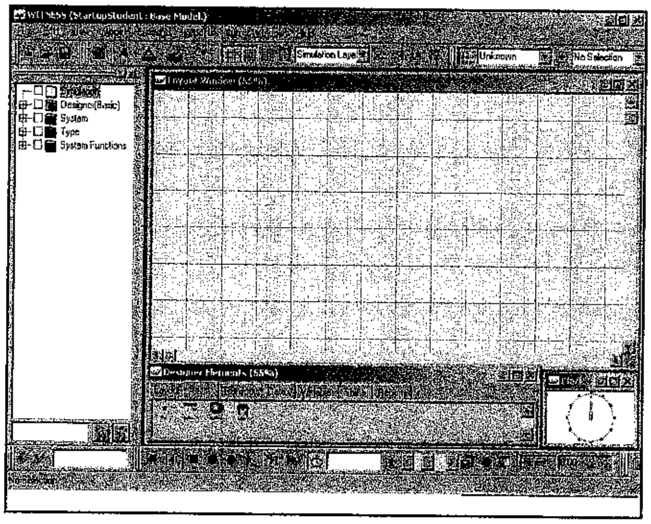

Figure 2.1 : The WITNESS interface.

On the other hand, the Toolbars help the user to quickly build WITNESS models. It is resizable. The visual rules dialog can be displayed by using the Visual Input Rules, Visual Output Rules, or Visual Labor Rule buttons. The rules are used to assign entity or the machine for the process flow. On the other hand, the interact box is used to exchange information with the user concerning the running of a model. There are only certain types of information that allows the user to copy and paste; text in notes, text in input and output rules, text in actions, text in labor rules, graphics drawn on the screen editor, element display information and element detail information.

In WITNESS's principle, there are three model design steps; define, display and detail. These steps can be performed simultaneously by using Designer Elements or in sequence, by using the Element Selector dialog box.

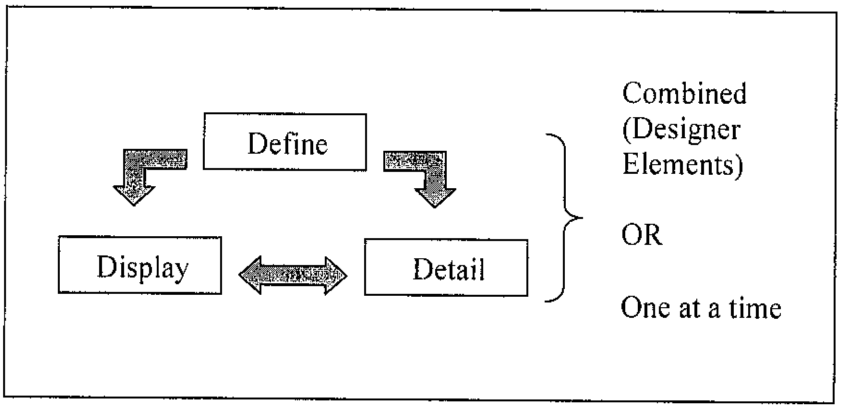

Figure 2.2: The Model Design Steps.

Table 2.1 : Steps to Building WITNESS Models

Steps	Description
Define	Define the major Elements that make up the 'building blocks' of the simulation.
Display	Display each of the Elements in order to build up a pictorial representation of the facility layout.
Detail	Specify the timings and routing of parts (entities) as they move through the model. Each Element type has its own characteristics. The logic for controlling the simulation is specified in this phase.

CHAPTER 3

METHODOLOGY

3.1 Activities.

In general, the project was performed within two semesters. The main activities could be summarized as follows;

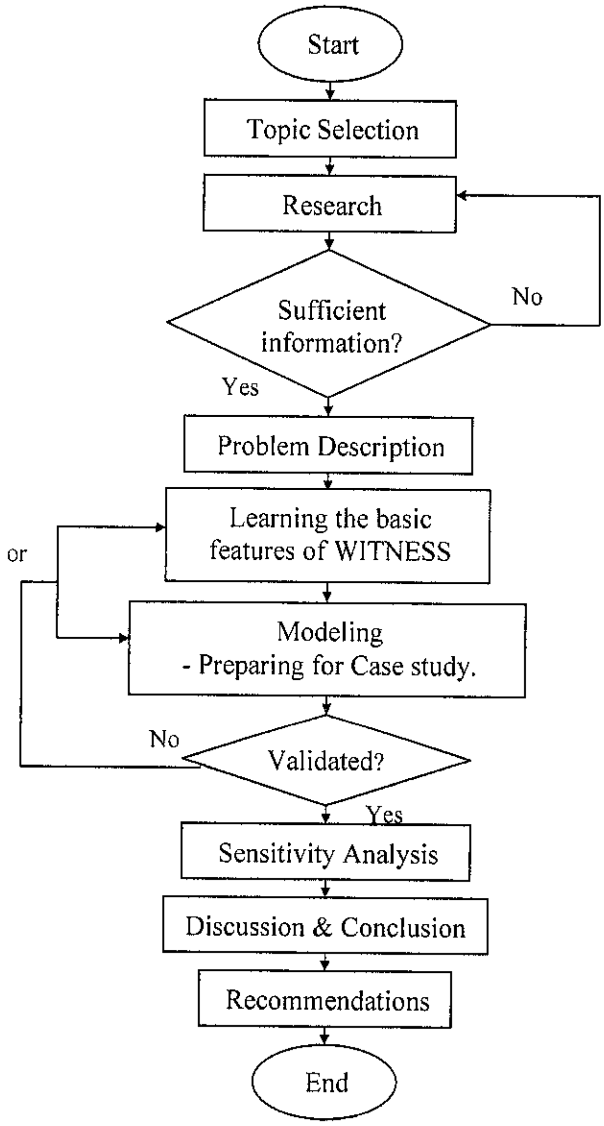

Figure 3.1: The activities throughout the First Semester.

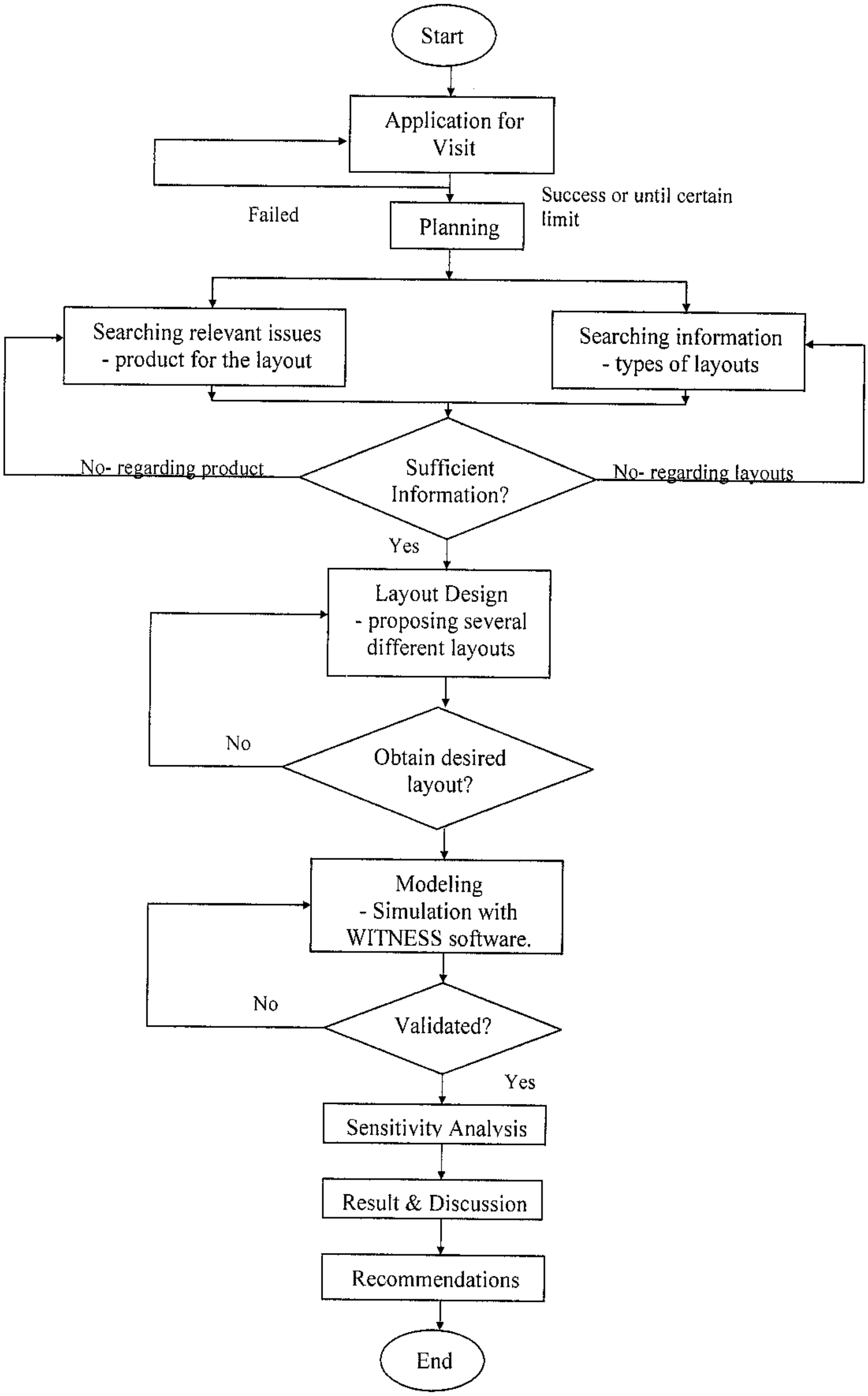

Figure 3.2 : The activities throughout the Second Semester.

3.2 Modelling with WITNESS software.

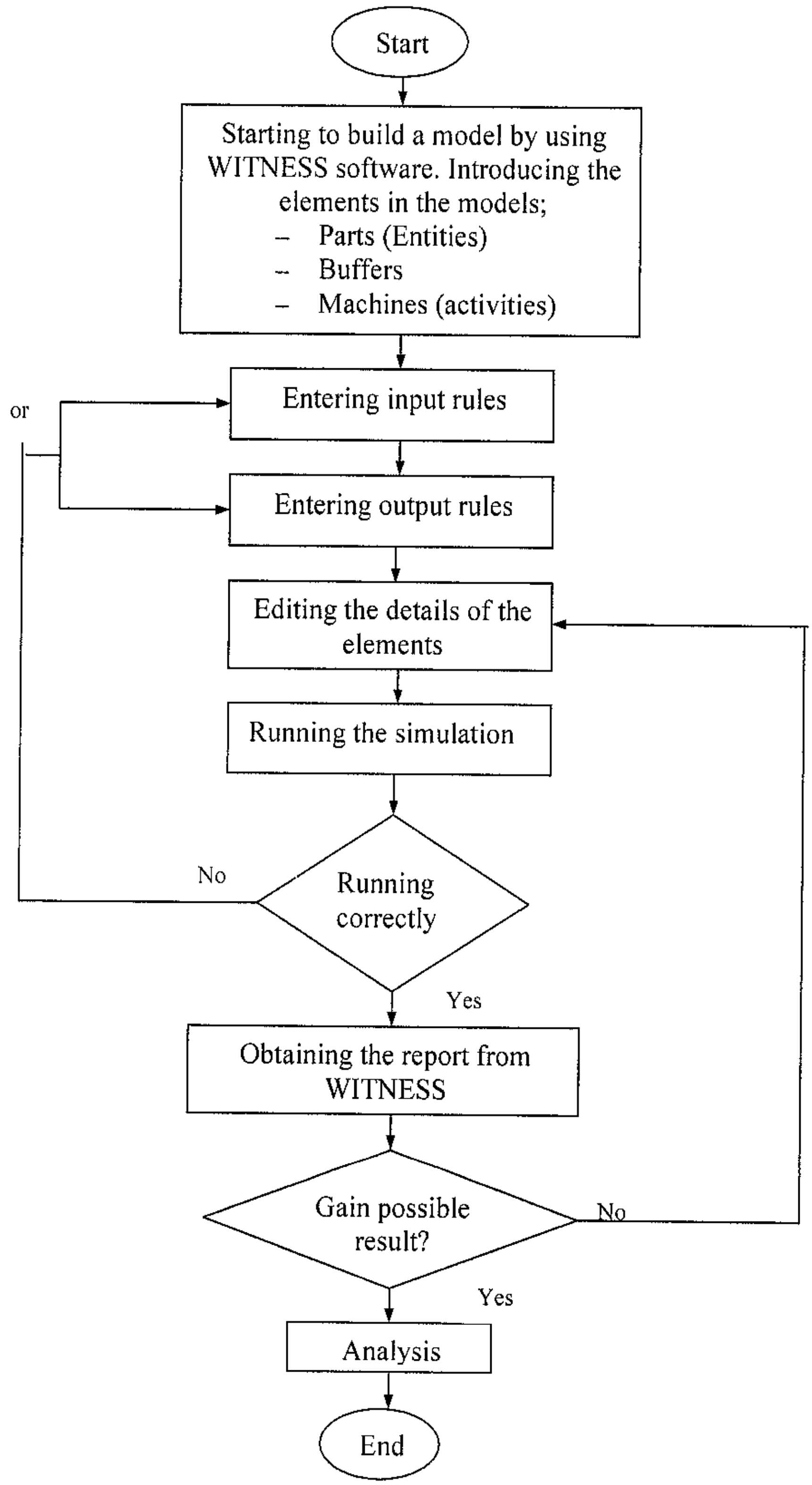

Figure 3.3 : The methodology of using WITNESS software for simulation

The process of using WITNESS software was started by introducing the elements in the layouts. For instance, for Design 1, the introduced elements were the parts (P1, P2, Acetone and sticker), the buffers (8 buffers) and machines that showed the activities or stations. The graphical display could be chosen from the picture gallery. The display could also be changed even after simulation. It could be done by clicking the *Elements* menu and then *Display*. There were many icons could be chosen by clicking to the selected picture.

Once the layout had been arranged, the input and output rules would be edited. This was to determine the flow of the process for particular entities and to set the condition in the machines. After that, the details of the elements should be entered. The details were the parameter of the entities, buffers and machines such as the cycle time, interval time, first arrival time, maximum capacity of the buffers, etc. These parameters were very important. If the data was inadequate, a box would come out to ask for the data which was incomplete. The simulation could not run if the important data such as inter arrival time of a part and cycle time of particular process were not given.

Once the processes had been completed, the simulation could be started by clicking the play button. In the project, the expression time had been set to be 960 minutes before starting the simulation. This referred to the daily operation that running 16 hours per day. While running the simulation, the sequence and the flow of the entities were observed in order to ensure it followed the rule that been set. If the flow was incorrect, the input or output rules were first to be checked. It could also be checked in the summary. Then, the report of the result could be obtained by clicking the statistics icon.

Finally, the result of the simulation was analyzed. The main data for the machines were like the busy percentage, idle percentage, blocked percentage, and number of operations. Based on the result of the machine statistics, the production rate and throughput time could be calculated. The value of WIP was directly given in the parts statistics.

Followings were the equations used in finding the production rate and the throughput time;

$$\text{Production rate} = \frac{\text{Numb. Of operations}}{\text{Numb. Of hours per day}}$$

$$\text{Throughput time} = \frac{\text{Numb. of hours per day}}{\text{Numb. of operations}} \times \frac{\text{60 minutes}}{\text{1 hour}}$$

$$\text{WIP} = \sum \text{WIP for each part}$$

The same method was applied for the other 2 designs. As for the sensitivity analysis performed in the Design 1, the first analysis only involves with changing the parameter in each part, whereby the inter arrival time was reduced.

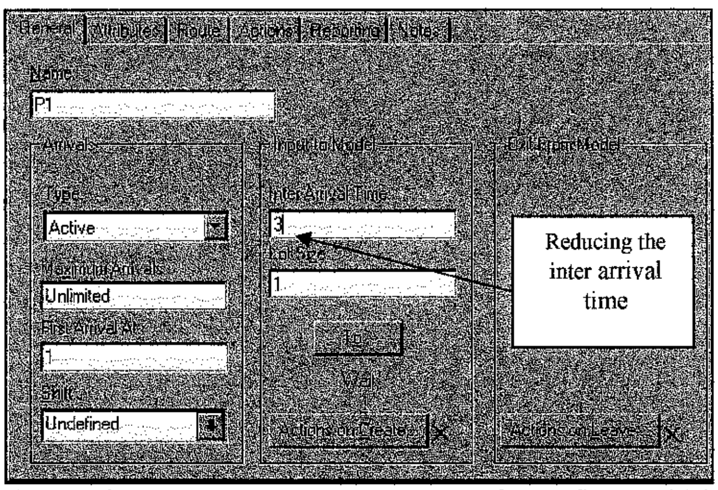

Figure 3.4: The Detail box used to change the parameter for the first sensitivity analysis.

For the second sensitivity analysis, the number of setting station was adding by performing as follows;

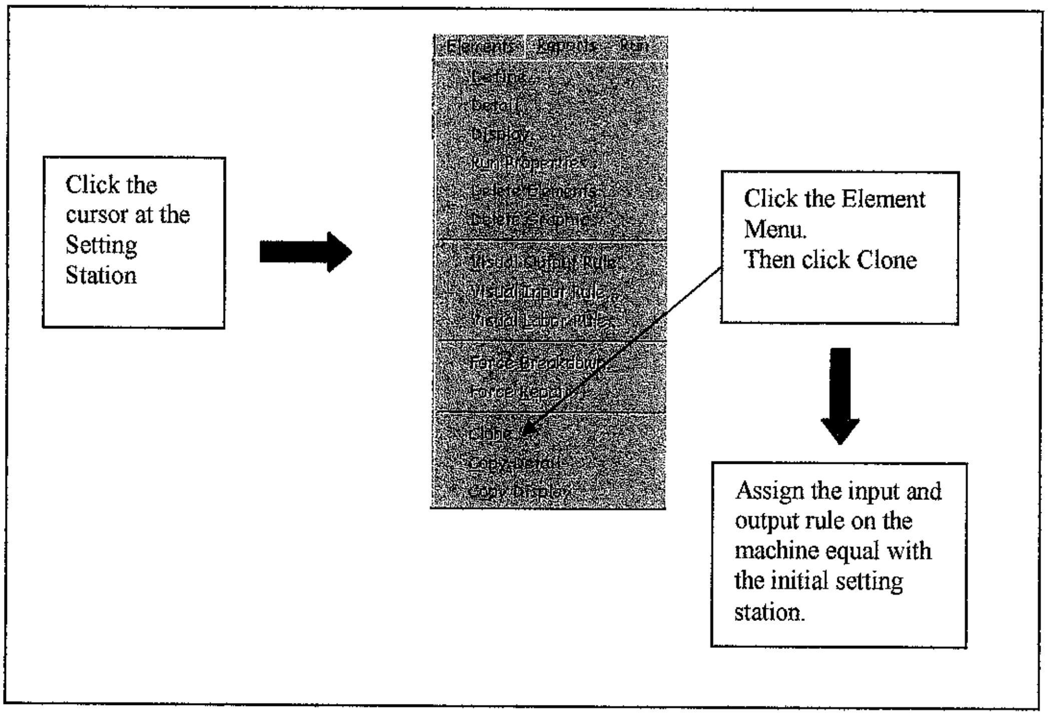

Figure 3.5: The changing made for the second sensitivity analysis.

3.2 Tool

The tool being utilized during the analysis was the WITNESS software. It was important for simulation process and sensitivity analysis. The stopwatch also had been used for time study in order to get the load and unload time.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Introduction

The Finder unit consists of Finder Base Plate (P1) and Eye Piece Lens (P2). Originally, there are eight main steps identified in producing the Finder Unit;

Table 4.1 : The steps to produce Finder Unit.

1. Blow the P1 with air gun.
2. Set the P1 to jig.
3. Blow the P2 by air gun and check appearance condition.
4. Set P2 to P1.
5. Apply Acetone to P1 and P2 (2 points) and hold .
6. Take out from jig.
7. Cut protection tape using tape cutter.
8. Peel protection tape from cutter and stick to P2.

There are three types of layout have been proposed. The layouts are manual assembly line (in-line), semi-automated assembly line (in-line), and single station assembly machine. Each system has slightly different process and number of machines involved. Besides, the cycle time for particular process is also different.

The constraint for the project is to design the layout in an area of 4m x 5m. There are two shifts of operation per day, whereby eight hours for each shift. The simulation would be performed on daily basis. The time expression being set for the simulation would be 960 minutes. (8 hr/shift x 2 shift/day x 60 minutes/hr).

4.1.1 Design 1: Manual Assembly Line (In-line)

Basically, the layout for this type of assembly line is similar with the original layout taken from a verified case study. It consists of two air guns, a station for setting the finder unit, a station for placing the protection tape, a cutting machine, and eight buffers. The inputs during the process are finder base plate, eyepiece lens, acetone, and protection tape. Besides, four workers are needed in this line.

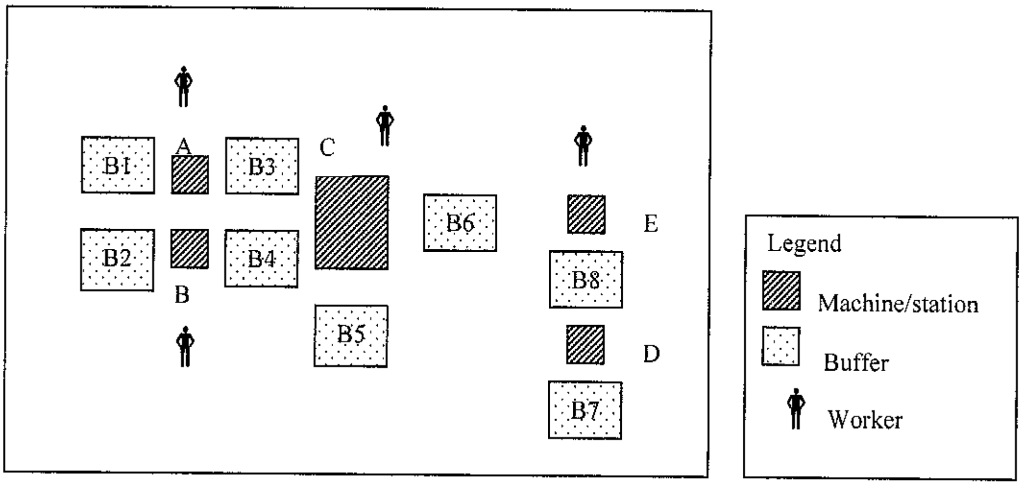

Figure 4.1 : The sketch of the layout of manual assembly line.

The raw P1 components are placed in B1. The process is started by blowing the finder base plate with the air gun 1 (Station A) for 0.9 minutes. The aim of the process is to ensure there would be no foreign particle on the finder base plate. After blowing, it would be placed on the jig in setting station (Station C). In parallel, P2 would also be blown for 1.98 minutes in Air Gun 2 (Station C). A worker is needed on each air gun station.

After checking the condition of the lens, it would then been set to the finder base plate. Acetone is used as the mechanism for both components to stick together. It is important to ensure that both components are well-stick by holding them in a certain period. Then, both would be taken out from the jig. The total cycle time for setting those components is 3.65 minutes. A worker is required to perform the assembly task.

Simultaneously, a cutting machine (Station D) cuts the protection tape. A worker in Station E peels the protection tape and sticks on the finder unit for protection purpose. This process takes about 0.8 minutes. Finally, the complete finder unit could be sent for assembly.

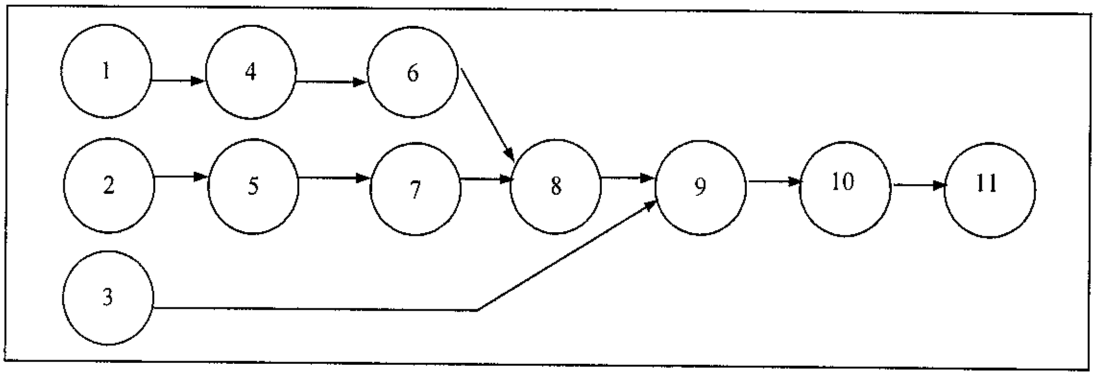

Figure 4.2 : The precedence diagram for Design 1. (Please refer to Figure 4.3 for the name of processes).

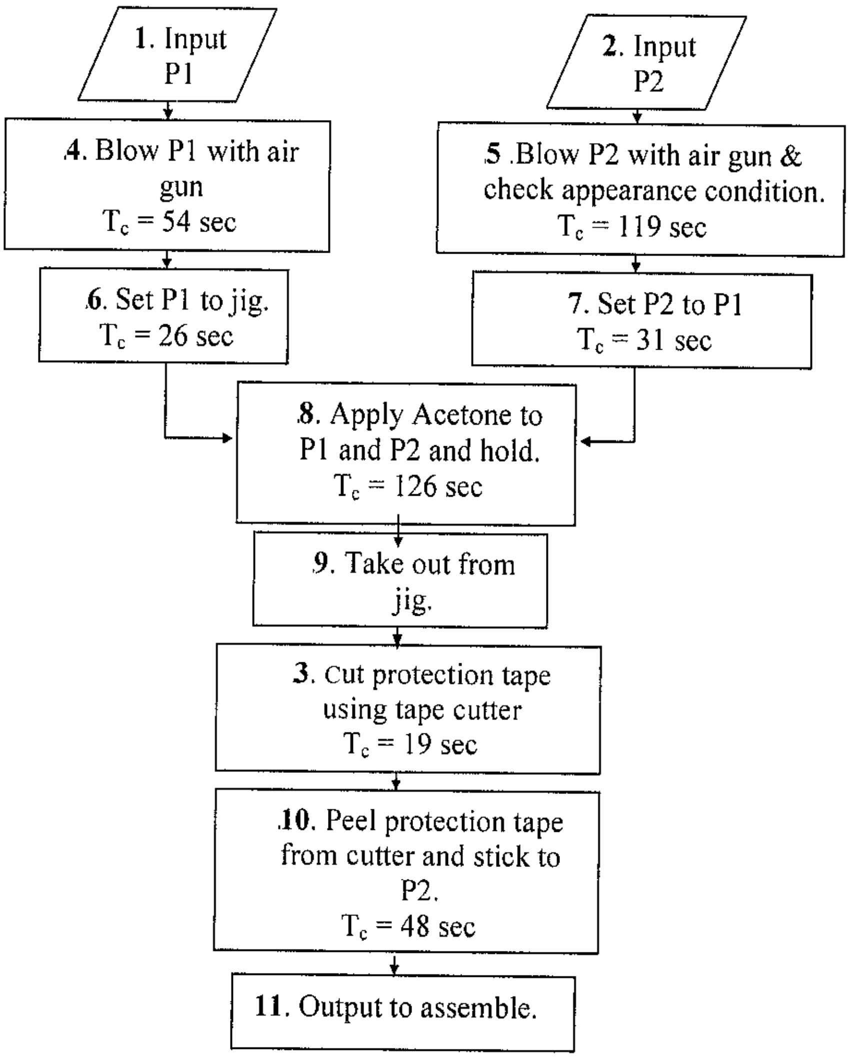

Figure 4.3: The process flow of producing finder unit for Design 1.

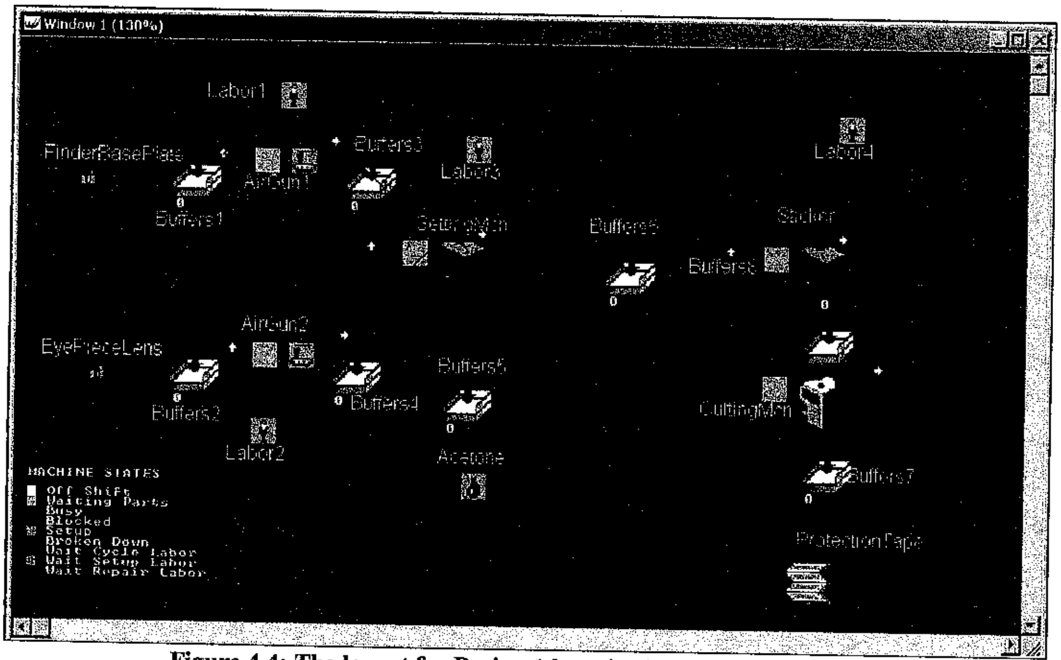

Figure 4.4: The layout for Design 1 by using WITNESS software.

4.1.2 Design 2: Semi-automated Assembly Line (In-line)

The second design is a semi-automated assembly line. It is considered as semi-automated because not all the processes are automated since a worker is needed to place the protection tape on the finder unit. In this type of assembly line, five robots have been introduced. Furthermore, the line includes five buffers, two air gun stations, a station for setting the P1 and P2 and a conveyor. The inputs during the process are finder base plate, eyepiece lens, acetone, and protection tape, which has already being cut.

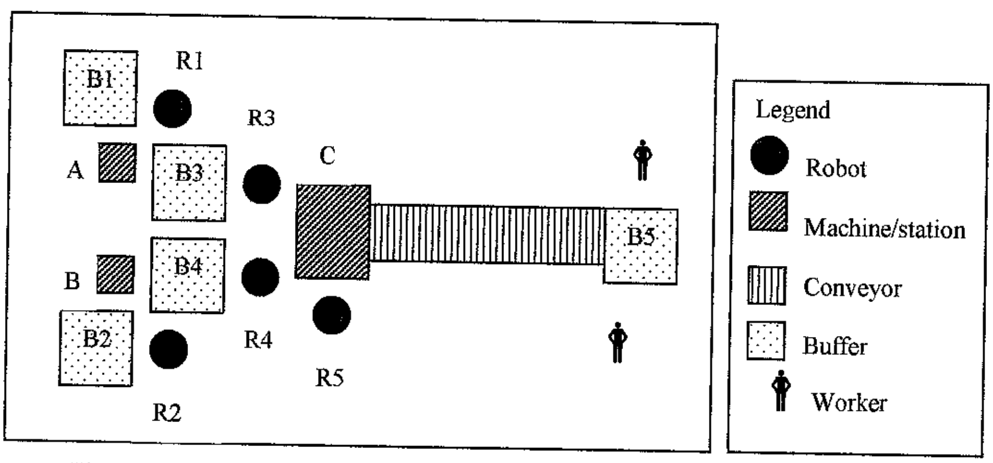

Figure 4.5 : The sketch of the layout of semi-automated assembly line.

Initially, 10 pieces of P1 are placed on a pallet that is introduced as a buffer, B1. The Robot R1 senses the appearance of P1 at B1 and takes it. It holds the P1 at Machine A, which is an Air Gun 1 station. Once it reaches in Station A, the air gun will automatically blow the P1 for 0.7 minutes. Then R1 puts the P1 on the pallet at B3. It repeats the sequence. In parallel, Robot R2 takes P2 from B2 and hold it at Air Gun 2 (Station B) to be blown for 1.50 minutes. Then, it puts P2 at B4.

After that, Robot R3 senses the P1 at B3 and takes it to be fixed on a jig at Station C. By following the sequence, Robot R4 will also sense the appearance of P2 and take it to be fixed on P1 which has been set. It is performed once the R3 completed fixing P1. When these two steps have completed, Robot R5 will apply acetone on both parts to make them stick. At this point of time, the part has already completed as a finder unit. The total cycle time for the processes is 3.3 minutes. Then a pusher pushes the assembled part to the conveyor. This 2 meters conveyor will convey the finder unit to a station whereby 2 workers will stick a protection tape on the finder unit for the purpose of protection. Finally, they put all the finder units in B5.

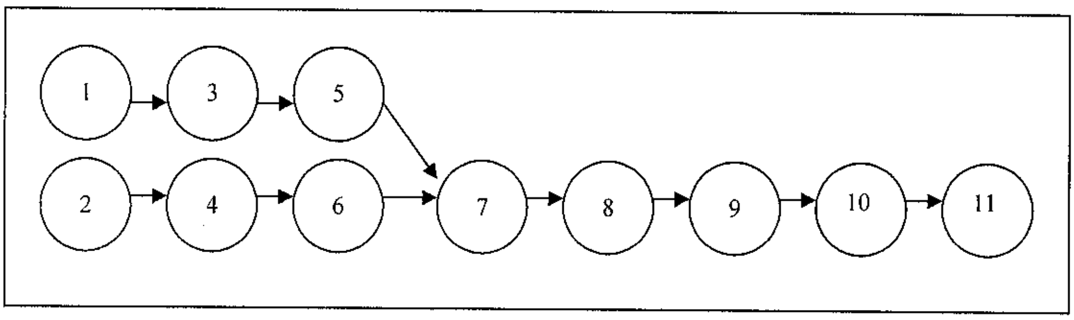

Figure 4.6: The precedence diagram for Design 2. (Please refer to Figure 4.7 for the name of processes.)

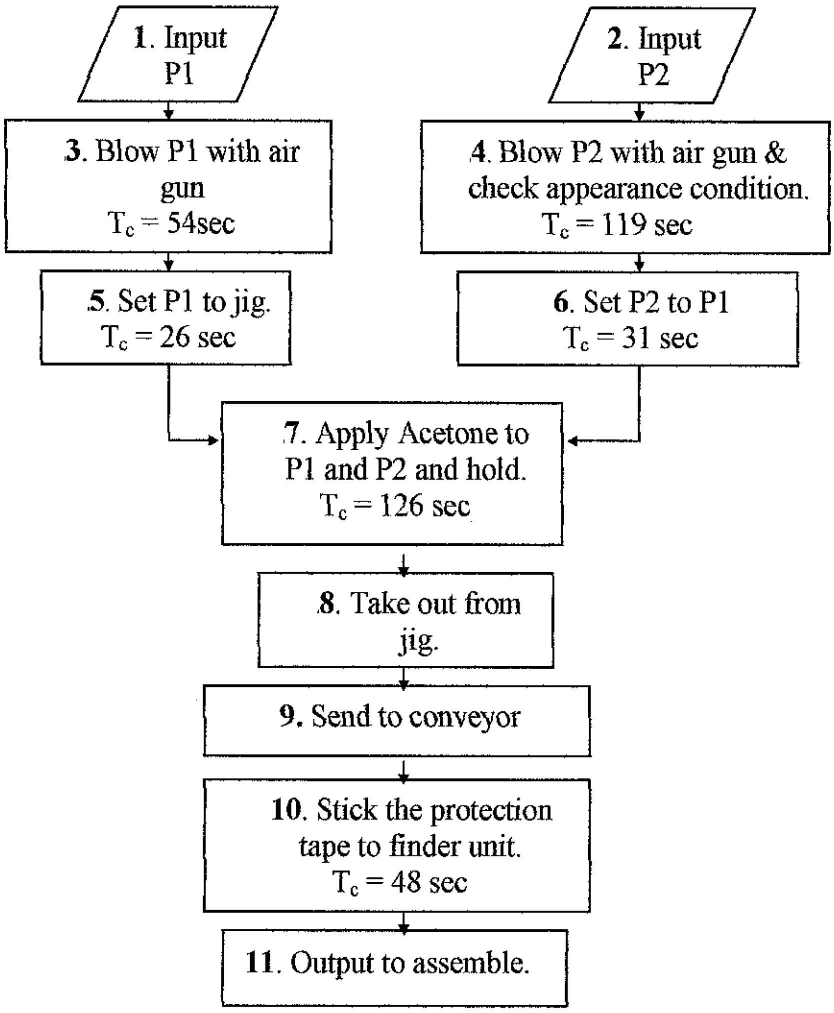

Figure 4.7: The process flow of producing finder unit for Design 2.

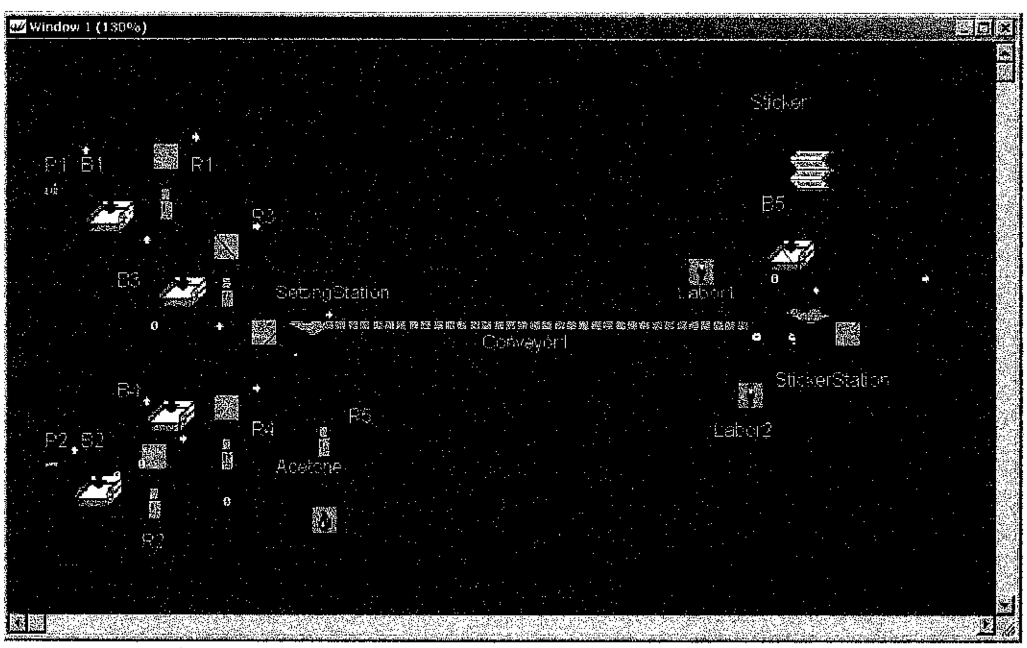

Figure 4.8 : The layout for Design 2 by using WITNESS software.

4.1.3 Design 3: Single Station.

The third design is a single station. It is a manual workstation. A worker is assigned to perform all of the tasks in a station such as blowing the P1 and P2 by using air gun, setting the P1 and P2 to the jig, applying the acetone and finally placing the protection tape on the finder unit. During the process, a table is needed to perform all of the task, an air gun, and 4 buffers. The inputs are P1, P2, acetone and protection tape that has been cut.

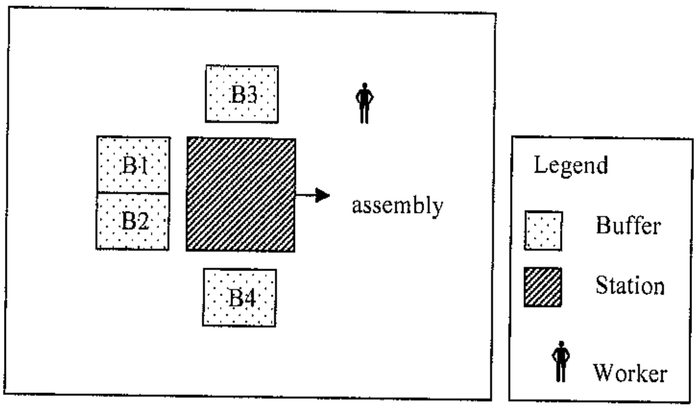

Figure 4.9 : The sketch of the layout of single station.

The process is started when P1 is taken from the pallet at B1. A worker blows the P1 by using the air gun located on the table for 0.9 minutes. Then, he sets the P1 on a jig. After that, the worker takes P2 from B2 to be blown by using the same air gun for 1.98 minutes. Then, he sets the P2 on the P1. The acetone is used to make both components stick together. Finally, he puts the protection tape on the finder unit before it is being assembled to the other station.

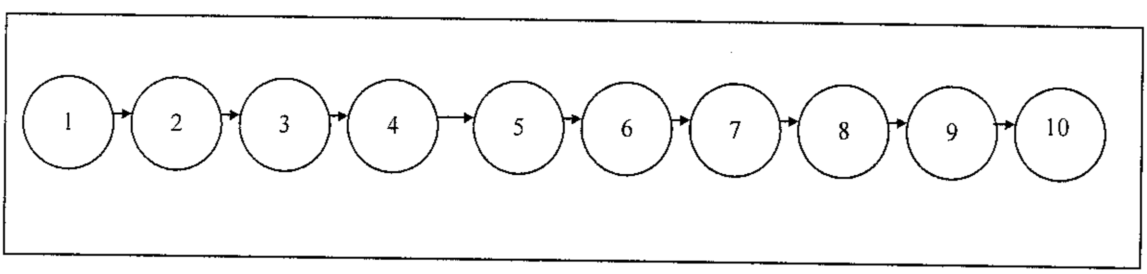

Figure 4.10 : The precedence diagram for Design 3. (Please refer to Figure 4.11 for the name of processes)

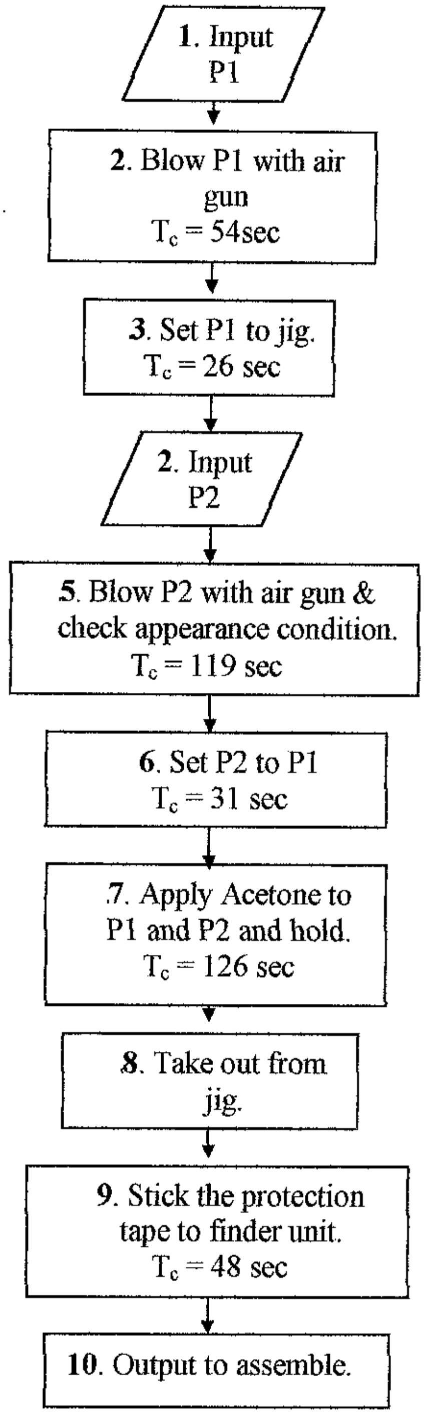

Figure 4.11: The process flow of producing finder unit for Design 3.

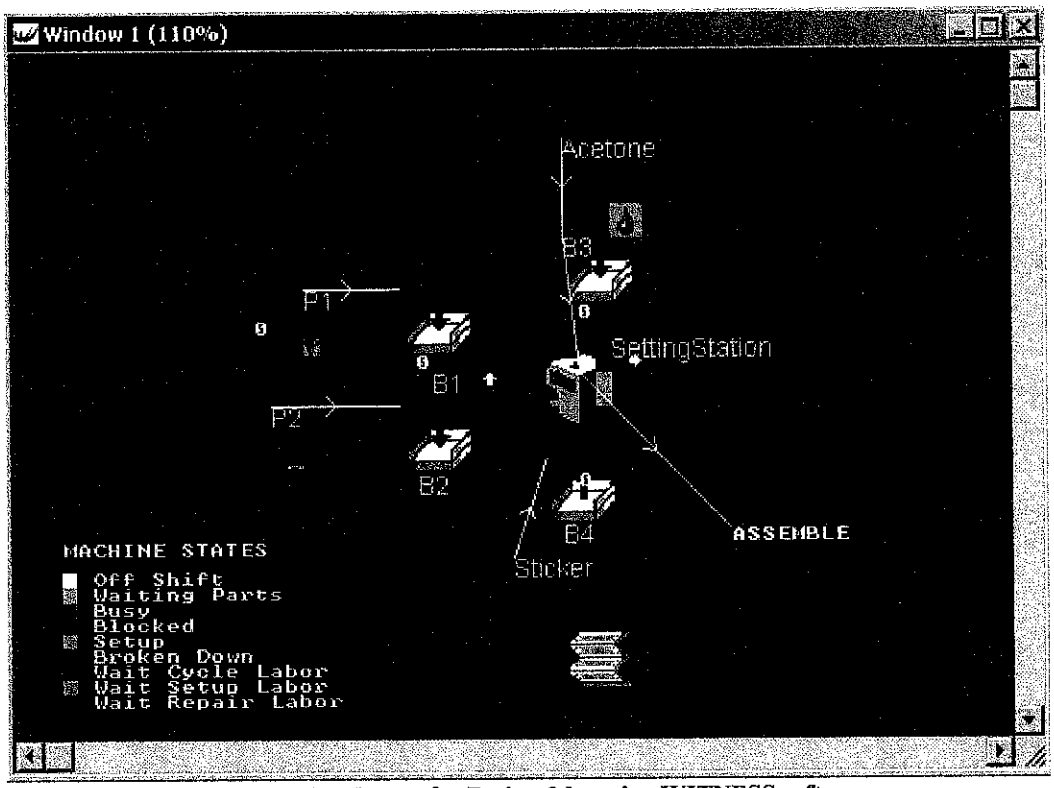

Figure 4.12: The layout for Design 3 by using WITNESS software.

Table 4.2 : The Inter arrival time for each part.

Part	Inter Arrival Time (min)		
	Design 1	Design 2	Design 3
Finder Base Plate	5	3	5
Eye Piece Lens	5	3	5
Acetone	3	1	5
Protection Tape	5	5	5

4.2 Analysis

Each sketch of the design was transferred to the WITNESS software layout. The simulation process was started with the first design, which was the original layout. The statistics of the simulation were observed and the results were recorded to be analysed. Followings are the performance of each machine or station for those three layouts;

Table 4.3: The machine statistics for Design 1.

Process	Air Gun 1	Air Gun 2	Setting Station	Cutting Machine	Sticker
Idle percentage	78.6	57.0	23.8	90.2	80.7
Busy percentage	21.4	43.0	79.2	9.8	19.3
Blocked percentage	0	0	0	0	0
No. of operation	192	192	192	191	191

Table 4.4: The machine statistics for Design 2.

Process	R1	R2	R3	R4	Setting Station	Sticker
Idle percentage	25.6	14.0	1.9	0.6	0.6	80.0
Busy percentage	32.8	57.8	10.3	10.3	99.4	20.0
Blocked percentage	41.6	28.2	87.8	89.1	0	0
No. of operation	302	301	292	291	289	240

Table 4.5: The machine statistics for Design 3.

Process	Setting Station
Idle percentage	0.1
Busy percentage	99.9
Blocked percentage	0
No. of operation	126

The term 'number of operations' in the tables depicts the number of parts produced in each station. It is used in WITNESS while indicating the machines statistics.

For better understanding during the analysis, the results had been transferred to the histogram form, as follows;

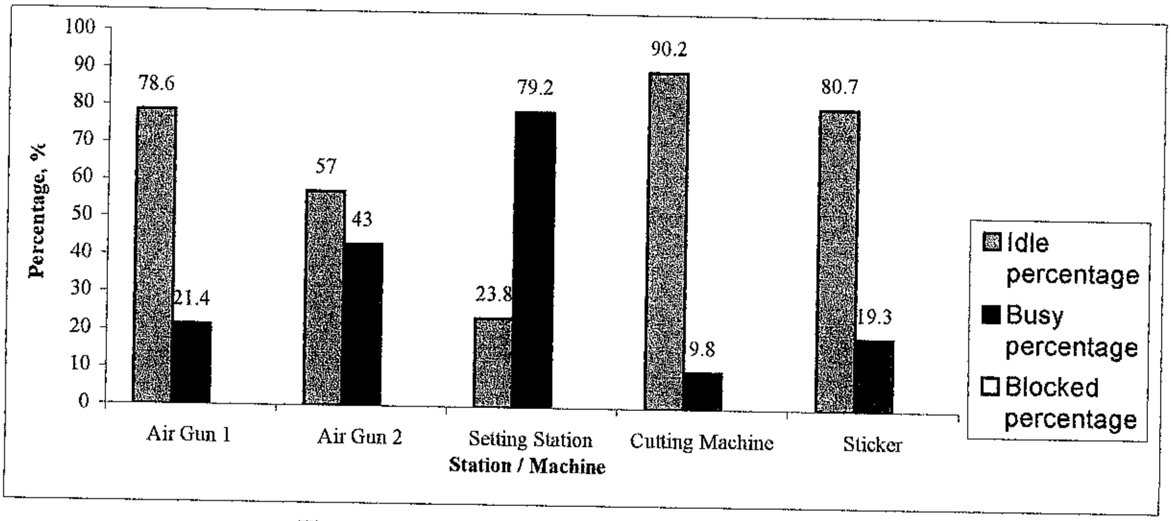

Figure 4.13 : The station/ machine statistics for Design 1.

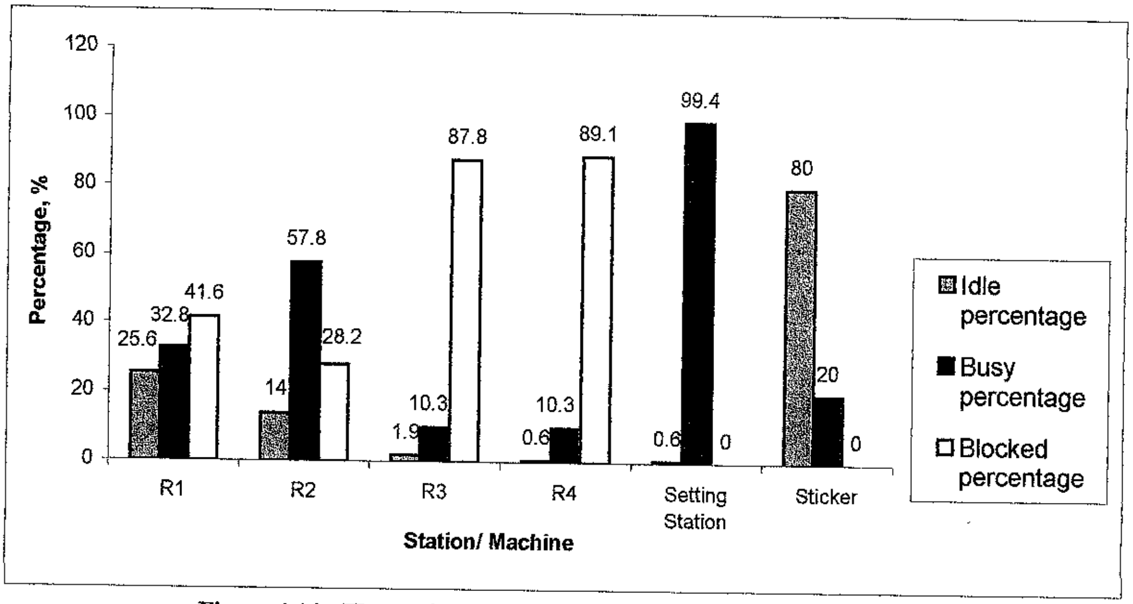

Figure 4.14 : The station/ machine statistics for Design 2.

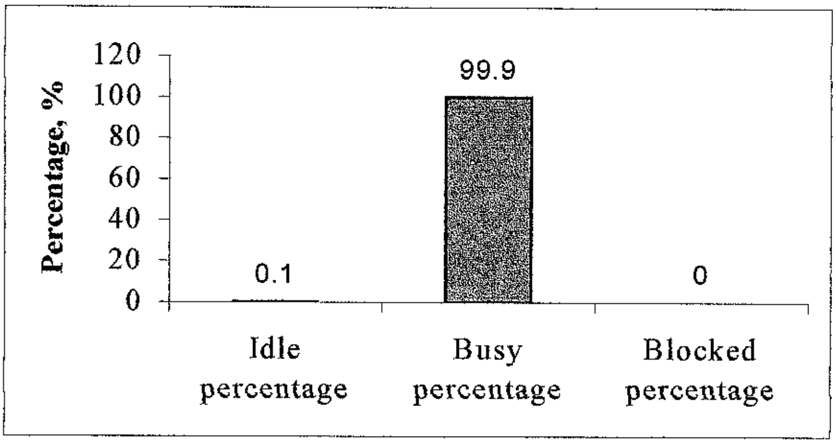

Figure 4.15: The station/ machine statistics for Design 3.

The machine statistics provided the number of operations for all machines. In order to know the total final product produced in the system, the number of operations at sticker station was observed. The sticker station was chosen because it was the final station in the layout that could indicate the complete product produced. The following figure indicates the number of final product produced in each design;

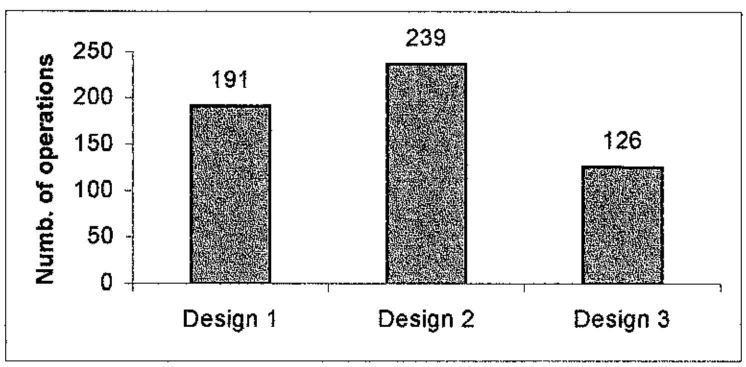

Figure 4.16 : The number of operations for each design.

On the other hand, buffers statistics also have been analysed. The following tables show the results of the simulation;

Table 4.6 : The buffers statistics for Design 1

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time
Buffer 1	192	192	0	1	0	0	0
Buffer 2	192	192	0	1	0	0	0
Buffer 3	192	192	0	1	0	0	0
Buffer 4	192	192	0	1	0	0	0
Buffer 5	201	192	9	10	0	9.29	44.37
Buffer 6	191	191	0	1	0	0	0
Buffer 7	192	192	0	1	0	0	0
Buffer 8	192	191	1	2	0	1.09	5.47

Table 4.7 : The buffers statistics for Design 2

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time
Buffer 1	312	303	9	10	0	4.14	12.75
Buffer 2	311	302	9	10	0	4.47	13.80
Buffer 3	302	292	10	10	0	7.92	25.18
Buffer 4	301	291	10	10	0	8.17	26.07
Buffer 5	10	0	10	10	0	9.85	946.00
R5	299	289	10	10	0	9.80	31.46

Table 4.8 : The buffers statistics for Design 3

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time
B1	137	127	10	10	0	8.95	62.68
B2	137	127	10	10	0	8.93	62.58
B3	137	127	10	10	0	8.90	62.39
B4	136	126	10	10	0	8.89	62.78

Based on the buffers statistics, the 'now in' value indicated the number of parts being stored in the buffer at 960 minutes of period. This value was also known as WIP. The parts statistics were also been analysed. From the statistics, the total number of WIP was obtained.

After the simulation, the three main measurements were calculated. The following table summarized the results;

Table 4.9 :The results for the designs.

Name	Production rate, unit/hr	Throughput time, min	W.I.P, unit
Design 1	11.9	5.03	13
Design 2	15.1	3.97	60
Design 3	7.9	7.62	42

On the other hand, the sensitivity analysis had been performed in Design 1. For the first analysis (A), the interval time for each input was reduced to 3 minutes where was previously 5 minutes. For the second analysis (B), the number of setting station was increased to be 2 stations. The following tables were the results for the analysis;

Table 4.10 : The machines statistics for 1A and 1B.

Process	Air Gun 1		Air Gun 2		Setting Station		Setting Stn 2	Cutting Machine		Sticker	
	A	B	A	B	A	B	B	A	B	A	B
% Idle	9.6	27.8	4.3	0.1	0.3	11.4	11.7	11.1	17.8	74.7	55.2
% Busy	29.2	52.0	58.7	99.9	99.7	88.6	88.4	13.3	23.2	25.3	44.8
% Blocked	61.3	20.2	37.0	0	0	0	0	75.6	59.0	0	0
No. of operation	262	466	261	446	250	222	222	261	455	250	443

Table 4.11 : The buffers statistics for 1A

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time
Buffer 1	271	262	9	10	0	7.47	26.45
Buffer 2	271	262	9	10	0	7.47	26.45
Buffer 3	261	251	10	10	0	9.29	34.17
Buffer 4	261	251	10	10	0	9.24	33.98
Buffer 6	250	250	0	1	0	0	0
Buffer 7	270	261	9	10	0	7.61	27.04
Buffer 8	260	250	10	10	0	9.45	34.89

Table 4.12 : The buffers statistics for 1B.

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time
Buffer 1	476	476	9	10	0	2.41	4.86
Buffer 2	456	447	9	10	0	8.16	14.18
Buffer 3	466	466	20	20	0	14.15	29.15
Buffer 4	446	446	0	1	0	0	0
Buffer 5	456	446	10	10	0	9.67	20.36
Buffer 6	444	444	0	1	0	0	0
Buffer 7	464	455	9	10	0	5.83	12.06
Buffer 8	454	444	10	10	0	9.15	19.35

Table 4.13: The results of the sensitivity analysis.

Name	Production rate, unit/hr	Throughput time, min	W.I.P
1A	15.6	3.84	72
1B	27.1	2.22	78

Based on Table 4.13 the production rate for the assembly line with 3 minutes inter arrival time of each input was the highest among others. It was 27.1 units/ hr. However, the WIP of the assembly line was also the highest among others, which was 78 units.

4.3 Discussion

The design of the layout is important to be utilized during the simulation. In order to perform the sensitivity analysis, three different layouts had been designated. The layouts are manual assembly line (in-line), semi-automated assembly line (in-line) and single station layout. Three measurements have been highlighted as to measure the performance of the layout. The measurements are the production rate, throughput time and work-in-process (WIP).

In manufacturing, the assembly line must be designed to achieve a production rate sufficient to satisfy demand for the product. Product demand is often expressed as an annual quantity, which can be reduced to an hourly rate. As for the project, the highest production rate could be taken under consideration in choosing the best layout. The throughput time is the time required to assemble a given assembly from start to finish. The best layout is designed to have low throughput time since it only takes few times to accomplish the task. On the other hand, the work-in-process also plays important role in determining the best layout. It is also considered as the inventory that is in the state of being transformed from raw material to a finished product. In the project, the lesser the number of WIP, the better the layout is. Many manufacturing companies sustain major costs because work remains in-process in the factory is too long.

The analysis was performed based on daily basis. The number of shift for the operation was 2. Thus, it made the time representation to be in 960 minutes in period.

By referring to the Design 1, there were five stations involved in the system. It was a manual assembly line that consisted of a sequence of workstations where assembly tasks were performed by human workers. Based on the result of simulation, it was found that the most busiest machine was at the setting station, which was 76.2% compared to the others such as air gun 1, air gun 2, sticker station and cutting machine which were 21.4%, 43.0%, 19.3%, and 9.8%, respectively. The setting station was deemed the most crucial station since it performed the important task in the assembly line. Furthermore, among all machines, the setting machine required longest time to complete the job and this made some others machine like air gun 1 and air gun 2 to wait for it. Upon performing job in setting station, other parts in prior buffer needed to be accumulated before been brought to the setting station. However, there was a maximum limit of the buffer whereby it should not exceed the maximum capacity, 10 unit parts. Once the parts reached at the maximum capacity, it could cause the part in the air gun station to be jammed and blocked. However, within the period of 960 minutes, there would be no blocking condition predicted by the simulation.

The results for the percentage of idle station were quite high whereby it were found higher than busy percentage for each station, except the setting station (23.8%). The idle percentage for air gun 1 and air gun 2 were 78.6% and 57.0%, respectively. It might due to the long period of inter arrival time for each raw material being brought to the assembly line. The idle percentage for sticker station was also high which was 80.7%. It was suspected due to long-waiting condition of the machine whereby it needed sometimes to wait for the output from the setting station. The blocked percentage for all station was 0%.

By referring to the result of the buffer statistics for Design 1, there were 8 buffers provided in the assembly line. The 'total in' indicated the number of part being input in the buffers, whereas the 'total out' indicated the number of part being out of the buffers. Overall, about 191 to 201 parts had been stored in the buffers. After daily operation running for 960 minutes, there were 10 parts remaining in the buffers, which were considered as WIP; 9 parts in Buffer 5 and a part in Buffer 8. Based on the result, it was also indicated that the highest average time was occurred in Buffers 5, which was 44.37 minutes. It means that the buffers stored the parts very long while waiting to be brought to the setting machine. It might be due to waiting condition of the parts in Buffer 5 while waiting the setting machine completing the job.

Based on the simulation, the final product produced in Design 1 was 191 units of finder unit. Thus, the production rate of the assembly line was *11.9 units/hr*, throughput time was *5.03 minutes* and the work-in-process (WIP) for the day was *13 units.*

In order to analyze the sensitivity for the system, several changes had been made. There were two main changes where the results had been recorded. One of the sensitivity analysis remained the equal layout design, but the parameter of the inter arrival time for each part had been reduced to be 3 minutes. After simulation, it was observed that the change was able to increase the production rate to be *15.6 units/hr* and reduce the throughput time to be *3.8 minutes* for each unit. However, the WIP was very high, *72 units.*

By referring to the result obtained from WITNESS, the percentage of idle machine and station had reduced. Almost all machines acquired higher busy percentage than idle percentage, except for sticker station. The setting machine recorded the highest percentage of busy machine with 99.7%, compared to air gun 1, air gun 2, cutting machine and sticker station which were 29.2%, 56.7%, 13.3% and 25.26, respectively. However, even though the decrement in the inter arrival time could increase the busy percentage for each machine, it introduced blocked condition in air gun 1, air gun 2 and cutting machine, which were 61.3%, 37.0% and 75.6%, respectively. This blocked condition occurred when the number of accumulated parts in the buffer (after the air gun) exceeded the maximum capacity. For example, when there was 10 accumulated parts in Buffer 3, it would not receive any part to enter unless the next machine suddenly took one part. When this condition occurred, the prior machine could not take out the completed part. It would only keep the part in the machine. Then, the machine blocked. The same condition happened to Buffer 4 and Buffer 8.

For the second analysis, the number of setting station had been increased to be 2 stations. To make the station effectively been utilized, a worker had been introduced at the new setting station. Based on the result obtained, it was observed that number of final product produced was drastically increased to be 433 units. Thus, the production rate was *27.1 units/hr* and the throughput time was *2.2 minutes*. However, the WIP increased to *78 units*. 85.9% of the WIP were stored in the buffers. (B1, B2, B3, B5, B7, B8)

The result of the simulation indicated that in general, the busy percentage of all stations in the B system increased higher compared to the previous two cases. The busiest machine was air gun 2 with 99.9%, whereas the air gun 1, setting station, setting station 01, cutting machine and sticker station were 52.0%, 88.6%, 88.4%, 23.22%, and 44.8%, respectively. The high busy percentage of air gun1 and air gun 2 was suspected due to the additional setting station. Both air guns needed to process more parts since there was double requirement from the setting station.

The layout in Design 2 introduced the semi-automated assembly line. It introduced the use of robot in handling particular task. In general, robot able to perform task in a constant cycle time throughout the day compared to human being. However, there were several task that human could perform more efficient compared to the robot. For instance, human worker easy to adapt with changes in the system rather than robot, because the robot needed to reprogrammed.

Based on the result, the setting station acquired the highest busy percentage, which was 99.4%, compared to the station like sticker station, which was only 12%. In this layout, R1, R2, R3 and R4 were declared as a machine. Those robots were assigned as a multiple cycle machine, since it had several tasks to be performed. Each task had different cycle time. The air gun task was included in both R1 and R2.

The setting machine was observed as the bottleneck station since it was quite busy to assemble all the parts together. Furthermore, it also caused the prior robots in the line to blocked. It was proved when the blocked percentage for R3 and R4 were recorded to be 87.8% and 89.1%, respectively. This problem could be resolved by increasing the inter arrival time for each raw part, so that the number of parts enter the assembly line would be reduced at particular interval. The high percentage of idle condition in the sticker station was suspected due to the condition where the workers needed to wait for the setting machine to complete the job. The workers also needed to wait for the parts that were transferred by the conveyor.

Based on the result obtained, the production rate of the Design 2 was *18 units/hr*, the throughput time was *3.33 minutes* and *66 units* of WIP. Based on the analysis, it was found that 58 units from the total WIP were located in the buffers.

In the Design 3, the single station layout was introduced. It was a manual assembly station. In this system, only one table was used by a worker who performed all the tasks from the beginning to the end. The results were much different after simulation compared to the other layouts. The final product produced had reduced to be 126 units. This was the least number of final products among all type of layouts. This made the production rate and throughput time to be *7.9 units/hr* and *7.6 minutes*. The WIP was *42* units.

At this point of time, the busy percentage of the setting station was very high. It recorded 99.9%, whereas 0.1% was recorded for idle percentage. The result indicated that the setting station was almost fully utilized with no blocked condition occurred.

The condition of the buffers had also been analyzed. For this kind of station, buffers were used to store each raw material before being taken to the table to be assembled. The average time for all buffers was approximately 62~63 minutes. This long average time might be due to the long cycle time of the processes performed in the setting station.

According to the aim of the analysis, it was to propose the best type of layout. Among the three measurements, the greatest weight was given to the production rate, then the throughput time and so the WIP. By comparing those systems, each station possessed its own advantages and disadvantages.

From the perspective of production, Design 1B acquired the best option. It was able to produce the greatest number of production rate, which was 27.1 units/hr. It also required shortest throughput time. In a daily production, within 960 minutes of simulation, it was able to produce 433 units of finder unit.

In term of work output per worker, the best design was the single station assembly line. A worker in the single station was able to produce 126 units of finder unit. Compared to Design 1B, five workers were needed to perform the job in the assembly line only to produce 433 units. It was also economically good design, since only a table and several tools were required. Furthermore, it necessitated a small space size. This enabled some addition number of the same stations. As a result, more products could be produced. However, this kind of station would no longer efficient for long-term basis because a man could not sustain to perform the task continuously in a long time period.

In order to produce a constant product quality, Design 2 which introduced the used of robots could be considered as the best choice. Robots were able to maintain the performance of the products. However, if some of the produced products were bad performance, there would be a probability of the others to have bad performance also.

The third measurement was the WIP. Even though Design 1B was able to produce better production, but it introduced the largest number of WIP. It indicated not a good sign. However, this problem could be resolved. A good planning and management in manufacturing floor could be applied in the system. In order to avoid losses due to the WIP, the five workers in the systems could be assigned to collect all the parts left in the assembly line to be stored in the inventory properly. This could be an important task other than cleaning the assembly line after completing the daily job. Besides, the workers also required to jot down the number of WIP for the record purposes.

The buffers also play important role in the assembly line. The use of the buffer should be planned properly. If the maximum capacity is too small, it could cause the prior machine to block. On the other hand, if the maximum capacity of the buffer is too big, somewhat it could contribute to the increment of WIP. The requirement of the buffer could also be analyzed by using the result obtained in the buffer statistics. If the maximum number of parts stored in the buffer is not significant, other simulation could be done by eliminating the buffer. If it does not introduce bottleneck condition, the buffer could be eliminated.

The results of the busy, idle and blocked percentages also contributed as merit in the sensitivity analysis. The Design 1A was again indicated a good result, since almost all of the stations attained higher busy percentage than the idle or blocked percentage. This indirectly showed the utilization of the stations were high. Overall, it could be concluded that the setting station for all designs acquired high busy percentage compared to the other stations.

In conclusion, it could be observed that the manual assembly system was able to produce better than the semi-automated system. In particular process, the human was able to pick the part easily rather than the robot whereby it needed to sense earlier before it could take it. However, there was an advantage of utilizing the automated system (robot) whereby it could maintain performing the job in constant compared to human. Human being possesses the limitation. In certain level of period, the cycle time in performing particular task may increase because they need to rest for a few moments. On the other hand, the single station system was unable to produce a big number of products within the specified period. This was due to the worker, which needs to perform all the tasks from the start to the end.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

In conclusion, the aim of modeling the assembly line of finder unit for camera by using WITNESS software had successfully performed within the time bucket. The use of the WITNESS software in the project could help much in modelling the layouts of the assembly line. It was very significant since it aided much in performing the sensitivity analysis. There were three types of layouts had been proposed; manual assembly line (in line), semi-automated assembly line (in line), and single station. Based on the modeling simulation, the in-line manual assembly line with two setting stations was selected as the best layout, since it was able to produce highest production rate (27.1 units/hr) and shortest throughput time (2.22 minutes). In despite of having good result in both measurements, it possessed high number of WIP that was 78 units. However, the problem could be resolved with better planning as mentioned in the discussion.

The aim to familiarize with the use of WITNESS software was achieved. It included the use in basic and advanced features. However, due to time constraint, there were many more advanced features that could not be applied in the project. Moreover, the current use of the software had already fulfilled the requirement of the project.

5.2 Recommendations

There were several recommendations proposed for further consideration;

i) To include more advanced feature in the project.

There is many more use of actions in advanced features. The powerful extra facilities could give more control in the actions. Some of the statements used in the advanced features are able to execute in a straight sequence. WITNESS also introduces modules and hierarchical modeling. Hierarchical modeling could help to gain a good planning in determining the success of a project. By using the advanced feature in the final year project, could save hours of modeling.

ii) To utilize more attractive display features.

WITNESS provides display features to represent element visually, as model backdrops or to enhance the display of a model. Apart from WITNESS icons, models can also use pictures in bmp, gif, jpg, dxf, emf, or wmf format. To make the model more attractive, the 3D model could also being introduced. It is suggested for the expansion to develop more attractive layouts by utilizing these various types of display features.

iii) To improve the system.

The current design indicates that the system only able to produce maximum production of 443 units. It is suggested for the continuation to find out the way to increase the production rate of the finder unit for about 50% increment. It is also important to discover the way to reduce the WIP. Controlling the maximum capacity of the buffer is one of the way to reduce the WIP. However, it must be planned carefully since it may cause the machine to blocked. In order to work for improvement, the percentage target of improvement should be set earlier.

REFERENCES

[1] Benjamin W. N,"Motion and Time Study", IRWIN, Ninth Edition,USA,1993

[2] Boothroyd, G.,P.Dewhurst, and W. Knight, "Product Design for Manufacture and Assembly" Marcel Dekker, Inc., New York, 1994

[3] C. Ray Asfahl, 1992, "Robots & Manufacturing Automation" , John Wiley & Sons,Inc., USA

[4] George E.D, " Engineering Design, A Material And Processing Approach", Mc Graw Hill, Third Edition, Singapore, 2000

[5] Groover, M.P, "Fundamentals of Modern Manufacturing: Materials, Processes, and System, Prentice Hall,New Jersey, 1996

[6] John R.L, Molly W.W, and Robert M.W, "Manufacturing Technology", Prentice Hall, USA, 1990

[7] M. E. Mandel and D.L Danner, "Motion and Time Improving Productivity", Prentice Hall, Seventh Edition, USA, 1994

[8] Mikell P. Groover, 2001, "Automation, Production Systems, and Computer-Integrated Manufacturing" , Prentice Hall Inc., USA

[9] Sunderesh Heragu, 1997, "Facilities Design" , PWS Publishing Company, USA

[10] WITNESS 2003 Training Manual, ASR Synergy Sdn. Bhd, Selangor.

< http://www.usd.edu/~rlau/assembly.htm>

< http://www2.konikaminolta.jp/english/products/consumer/camera_pus/slr>

<http://www.statistics.gov.my/English/keystats.htm

APPENDICES

APPENDIX 1A

THE SYSTEM CHART OF A CAMERA

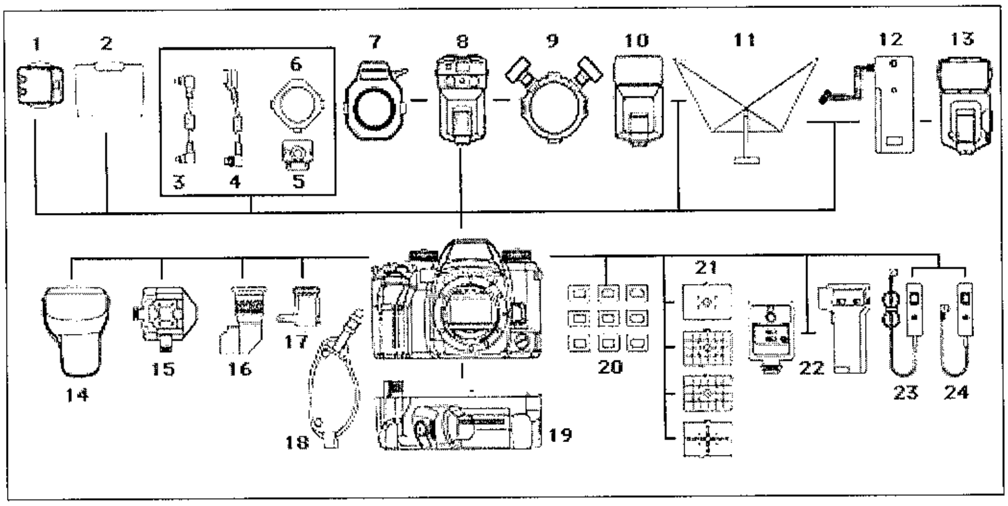

Figure 1A (1):The System Chart of a Camera.

1. Data Saver DS-100
2. Close-Up Diffuser CD-1000
3. Cable CD
4. Off-camera Cable OC-1100
5. Off-camera Shoe OS-1100
6. Triple Connector TC-1000
7. Macro Ring Flash 1200

8: Macro Flash Controller
9: Macro Twin Flash 2400 (lighting set)
10: Program Flash 3600HS(D)
11: Bounce Reflector V Set
12: External Battery Pack EP-2
13: Program Flash 5600HS(D)
14: Camera Case
15: Slide Copy Unit 1000
16: Angle Finder VN
17: Magnifier VN
18: Holding Strap HS-1
19: Vertical Control Glip VC-7
20: Eyepiece Corrector 1000
21: Focusing Screen
22: Remote Control IR-1N Set
23: Remote Cord RC-1000L
24: Remote Cord RC-1000S