THE PRODUCTIVITY IMPROVEMENT USING ARENA SIMULATION: A CASE STUDY OF ELECTRIC FAN PRODUCTION LINE MANUFACTURING

By
CHAIRAT THAMMATUTTO

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Master of Science in Supply Chain Management

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A Study of Improvement in Productivity Using Simulation: A Case Study of Electric Fan Production Line Manufacturing

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Abstract

Research questions – The improvement in production line consists of some important factors that affects the inventory level, production efficiency and the total cost of the production. This study focuses on the method of simulation which all concern about production line. The purpose of this study is to investigate and determine the optimal method to improve production efficiency by considering work-in-process, production efficiency, productivity, lead time, and effectiveness.

Methodology – This paper applies the concepts of cellular manufacturing and production line balancing techniques with Arena simulation software and mathematical methods via the case study of an electric fan manufacturing.

Contribution – The paper attempts to contribute to a better understanding and the comparison of performances of the current process to the proposed process whether and how much the new system could improve all key performance indicators.

Scope – The scope of this paper is to investigate a regular electric fan company without special marketing activities, such as promotion or new launch period.

Acknowledgements

It is my pleasure to acknowledge all those who assisted me with this graduate project. Firstly, I would like to express my gratitude to my advisor, Dr. Chayakrit Charoensiriwath, who was abundantly helpful and so kind and offered invaluable assistance and guidance over the course of it, without his support, this project would have not been possible. Sincere gratitude is also due to the members of the examination committee, Dr. Ismail Ali Siad and Ajarn Piyawan Puttibarncharoensri, for valuable suggestions.

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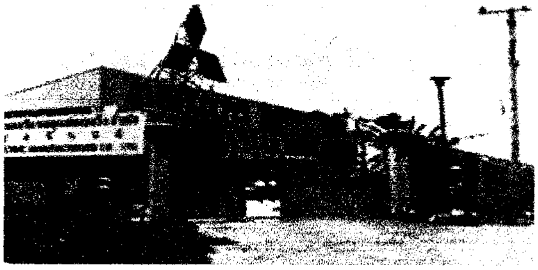
CHAPTER I

INTRODUCTION

In the world of manufacturing business, many companies are trying to run their businesses smoothly in a continuously changing situation. These tough situations not only contain uncertainty of customer demand, critical competition, and increased cost of material and labor, but also the present global economic crisis. Also, Thailand is currently confronted with a political problem. As a result, it is hard for business owners to encounter all the problems without any tools or techniques. These problems widely affect manufacturers. Even a big company such as Kang Yong Electric Public Company Limited (KYE) Mitsubishi Electric, the strongest electrical compliance manufacturer in Thailand, is affected. Although these problems cannot be avoided, what the management team must do is understand the problems, and then analyze and identify the best solutions, including discovering other new techniques.

1.1 Company Background

Kang Yong Electric Public Company Limited (KYE), previously known as Kang Yong Electric Manufacturing Co., Ltd., was founded on January 12th, 1964 with the registration number of 162/2507. It is located at 240 Moo9, Theparak Road, Tambon Samrong Nua, Amphur Muang in Samutprakarn. The company is a joint venture between Mr.Sithiphol Phodhivorakhun, the company's founder, Mitsubishi Electric Corporation Japan, Mitsubishi Corporation Co., Ltd., and a number of investors. It manufactures electric fans under the "Mitsubishi" trademark.



Kang Yong Electric Public Company Limited is presently located on a 72 rai, 1 ngarn, and 52 square wah premises at 67 and 67/1 Moo 1 1, Km20. Bangna-Trad Road, Tambon Bang Chalong Amphur Bangplee in Samutprakarn. The company is a leading manufacturer of such household appliances as electric fans, refrigerators, water pumps, and washing machines. The company is responsible for the international marketing of these products, while Kang Yong Watana Co., Ltd., is its sole representative in Thailand.

The company's shareholders include:

1. The Mitsubishi Group 41%

2. The Phodhivorakhun Group 25%

3. Representative groups and other investors 34%

Mitsubishi Electric Corporation is currently the largest stockholder.

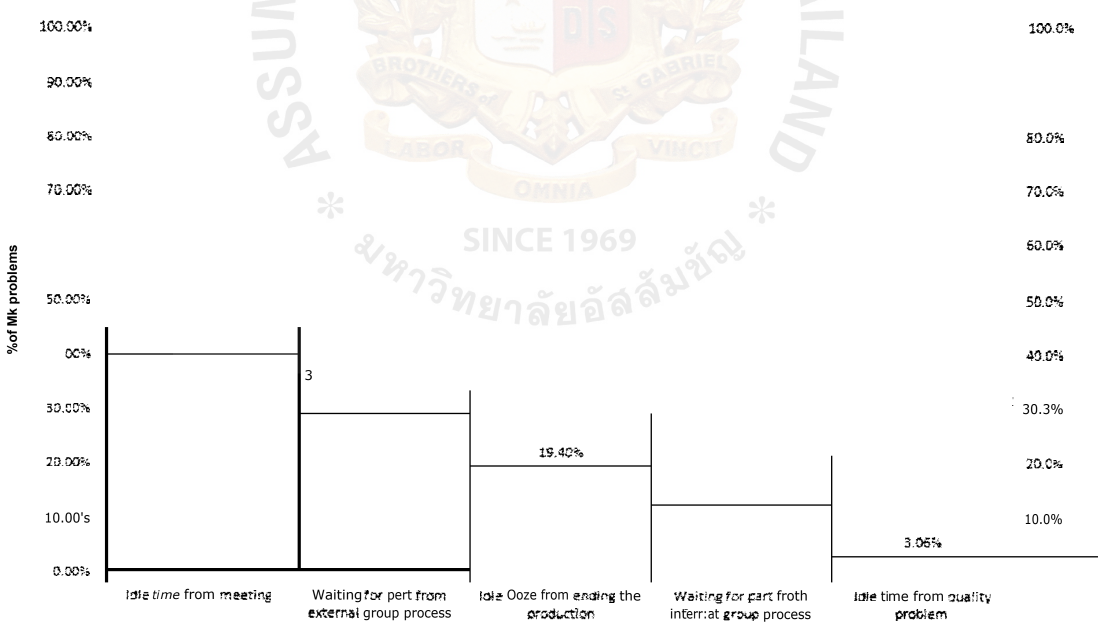
1.2 Statement of the problems

It seems that it is so hard for manufacturer to reduce their production cost and increase their productivity with optimal resources such as time period, manpower, or supply. How can the optimal number of labors be identified to match the customer demand? This question is a constant concern in meeting of the production department.

In KYE's case, they are confronted with demand fluctuation because of the cheaper price of products made by the competitors in China, and high demand in summer time. These lead KYE to other problems. For example, low utilization of resources, and over stock of inventory which costs them more than 15% of total assets or 500 million baht. Cost reduction in production is the most important thing for KYE because their selling price is 50 % more expensive than their competitors, both domestic and oversea. One of the reasons for this expensive production cost is waste in the production line.

Hence, production time minimization is another concern of the firm. Figure 1-1 shows a Pareto chart which describes the adverse impact of the waiting time for components, which happens because of more or less production quantities compared to customer demand.

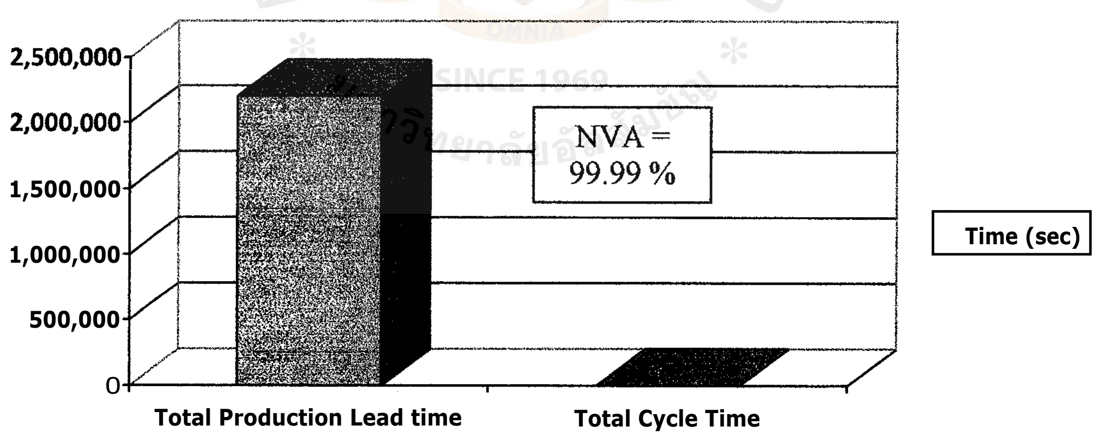
Figure 1-1: Pareto of time waste in the production line



Idle time from meeting cannot be ignored. But the rest are the problems which need to be handled. However, from the chart, the quality problem seems to be an inessential issue. Therefore, this study will concentrate only on production process issues.

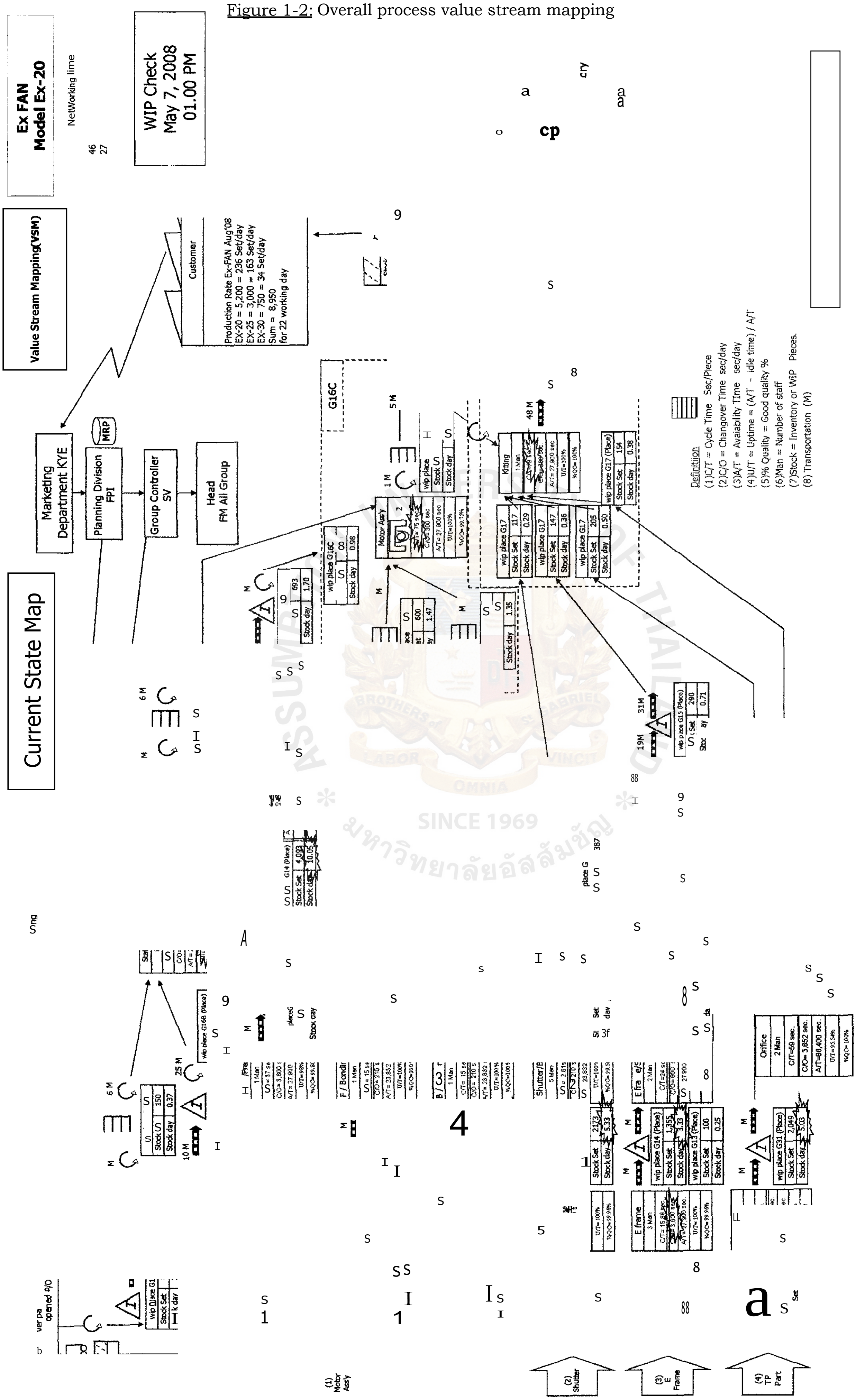
Moreover, we investigate value stream mapping of the overall production process in Figure 1-3. The long production lead time is 79.01 days. This means that the finished goods can be produced after an injection of money for buying raw-material, which is a very long time. At around 2.5 months, the company can waste money on raw-material and work-in-process of more than 10 million baht. If we compare 782.58 seconds in total cycle time and 79.01 days for total production lead time, there is some significant difference in the result. In Figure 1-3, 99.99% is due to waste of raw material and work in process waiting time. Some wastes can be eliminated at the same time and some cannot: for example, a big roll of metal sheet, a huge lot size of rotor shafts, and motor coils, because KYE has to order these in a fixed lot size from the supplier.

Figure 1-2: Graph comparing total production lead time and total cycle time



Value Stream Mapping of Overall Process

Figure 1-2: Overall process value stream mapping



In addition, the waste of work in process caused by a mismatch between production batch size and actual production through the production system, can be eliminated, such as, work in process of motor stator in the varnish oven process, inserted coil, and finished fan motor as in Table 1-1. From the Table it can be seen that WIP is similar to cumulative value through the production line. So, in total KYE waste money from just one fan model, around 700,000 baht, which is quite a lot. If we plan to reduce these kinds of WIP for the overall fan model, we can safely save the company a large amount of money.

Table 1-1: Work in process value along the production line

Check WIP Motor Ass): EX-Fan (all)

Production		Check WIP	Unit	Time					Avg	Process Cost (฿)	Process Value (฿)
				8:00	10:00	12:00	14:00	16:00			
Group 16A	1	Raw Matterial of motor co	(Kg)	1.416	1.416	1,416	1.416	1.416	1,416	333	471,840
	2	Motor Coil M(	(set)	150	150	300	450	600	330	35	11,492
	3	Motor Coil S	(set)	600	450	300	300	490	428	29	12,304
Group 16B	4	Forming 2	(set)	20	6	0	3	10	8	85	662
	5	Make up	(set)	14	4	2	4	6	6	97	584
	6	Check Scope	(set)	36	140	10	90	76	70	99	6,948
	7	Vanish & Oven	(set)	351	351	589	238	342	374	105	39,340
Group 16C	8	Stator Man1	(set)	300	190	400	350	270	302	105	31,750
	9	Finish good fan motor	(set)	730	530	600	650	500	602	172	103,609
										WIP Total	678,530

However, we can analyze more from the consolidated balance sheet for 2008. From the cash cycle calculation of KYE for 2008, we can see the AAI (average age of inventory) is 35 days, ACP (average collection period) is 30 days, and APP (average payment period) is 46 days. The 35 days of total inventory seem to be unnecessarily high. Controversially, KYE claims to be a lean manufacturing company with everything just-in-time. But, why do they need to keep inventory as long as 35 days? If they can reduce this inventory, it would mean a high reduction in cost.

In conclusion, it seems that KYE waste a lot of time in work in process, waiting to use the next process. But in actuality, the role of just-in-time means KYE has to produce the right product, in the right place and at the right time, which is called small batch production. We know that too many people cause many problems. So, cellular manufacturing can reduce these kinds of waste and improve productivity. Because of too many constraints, we cannot make all these improvements without the tools to let us analyze more precisely.

1.3 Research Objectives

The objective of this study is to investigate how smaller batch and cellular manufacturing at KYE affects to the inventory level, efficiency, and productivity in their production line. Other than that, optimal resources and WIP are the key benefits for production. The balance sheet report of KYE for 2008 implies that the cost of goods sold is more than 90% of total revenue, which costs the company about 6,000 million baht per year, while the inventory level is 15% higher than the total assets of the total company of about 500 million baht per year. As a result, if we can roughly calculate a 10% saving from this project, a huge amount of money could be saved by the firm.

The tool used in this study is ARENA, a simulation program. It could help to guide the company to reduce unnecessary time and identify the optimal solutions and also produce more accurate result in the KPI (Table 1-2 below).

Table 1-2: KPI for this project

KPI	Current	Target	Change
Overall Work-in-process (1000 baht)	100	50	-50 %
Production Lead Time (days)	3.41	1.00	-70.67%
Production effectiveness (Units /man / month)	728.45	1,000	+37.27 %
Production efficiency (CT / 3*61.89 %)	64.10 %	80 %	+24. 80 %
Machine Change over (Idle minute / month)	596	400	-30 %

For reach the KPI targets, means that KYE need to do process reengineering. Simulation of a new "design should produce a new scenario." So, when KYE need to change some production factor, such as number of employees, reduction in the production batch size or re-layout of the production line, it is hard to figure out the best solution for target KPIs without adverse impact from others. It seems that simulation can answer the question. From Carson (2005), simulation is a powerful tool for the evaluation and analysis of new system designs, modifications to existing systems, and proposed changes to control systems and operating rules.

In addition, when we need to solve the problem with a simulation program, we have to choose suitable software because each software has advantages and disadvantages at the same time. For this reason, this project chooses ARENA simulation software because of several factors:

1. It is worldwide.
2. High accuracy.
3. Add-in with result analysis program.
4. Full version supported by NEC IEC.
5. Easy to present the result in animation mode.

In conclusion, we can improve the KPIs by using re-engineering with ARENA simulation software without risk or wasting time, and a budget to compare with actual work.

1.4 Scope of the Research

KYE produces many kinds of home appliance products, such as fans, refrigerators and water pumps. However, this study will be specifically concerned with fan production, as right now KYE are implementing cellular production. In the cell production of fans in KYE, they are trying to implement the first pilot project on some products, not overall items. Another improvement project, which is within the scope of this research, is to adapt the new optimized production to other kinds of product, such as living stand fans and exhaust fans. In conclusion, the scope of this research will concentrate on the two kinds of product, as in the following detail.

Firstly, we try to understand the most important work in process, which involves electric motor because that greatly affects efficiency and effectiveness for all types of fan. Secondly, we plan to improve the KPIs for exhaust fans, which are currently produced in cellular mode for particular models. Lastly, further implementation will involve the stand living fan, which is now produced by conveyor line.

1.5 Limitations of the Research

The fan production plan of KYE is quite smooth. However, sometimes, the customers' demands cause a rush in the production process. As a result, this kind of uncertain demand could cause some errors in the simulation result. Hence, this research does not include these kinds of incidents in the simulation.

1.6 Significance of the Study

This production simulation research would be fruitful for the firm, for three reasons. First, the company can refer to the minimal time to find out the best optimal solution for production process improvement. Second, the animation of the ARENA simulation program could illustrate the overview of all production processes which will let the company recognize and reduce the hidden wastes such as work-in-process and low utilization rate. Third, the improvement would be easily shown in the financial statement which can lead the firm to see which changes could eliminate the problem and achieve more cost saving results, which definitely impact on the Key Performance Indicators (KPIs).

1.7 Definition of Terms

KYE is Kang Yong Electric Public Company Limited.

Objective Value is the target of the improvement result.

\VIP is work-in-process. In Manufacturing, parts, or subassemblies that are not part of the raw materials and not yet part of the finished goods inventory. Work in process inventory is a part of the working or current assets of a company and is valued usually at lower cost and realizable value. Sometimes it is also called work in progress.

Lead time is the period of time between the initiation state of any process of production and the completion of the process.

Cycle time is the period required to complete one cycle of an operation; or to complete a function, job, or task from start to finish.

Change over time is the period required to prepare a device, machine, process, or system for it to change from producing the last good piece of the last batch to producing the first good piece of the new batch.

Value added time is the period that the product creates value.

Non value added time is the period that the product is not creating value, and it sometime called waste.

Utilization is the percentage of using a resource for creating work.

CHAPTER II

LITERATURE REVIEW

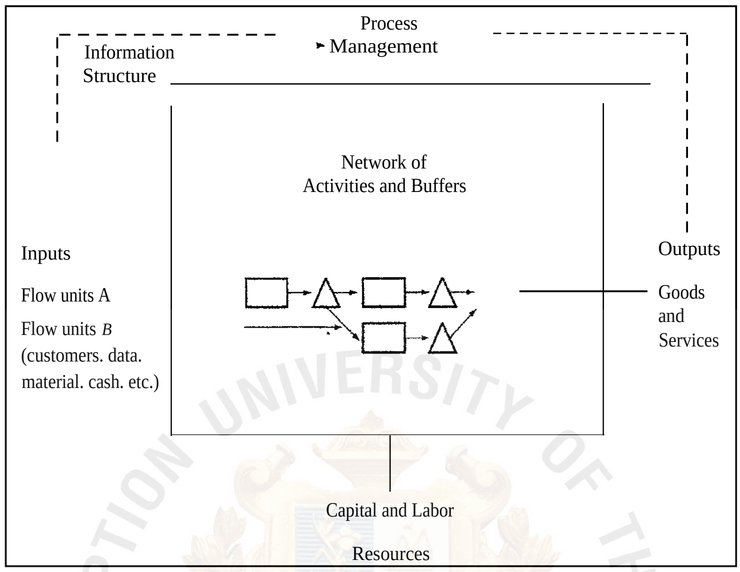
Currently, running a business without technology is similar to using a cart in this century. Production departments of most companies are finding new methodologies to reduce what they call wastes in the production process. But, how can they identify them within the project period? Moreover, if they can specify the waste, how can they know what is the best improvement for them in term of efficiency, effectiveness or investment cost? These are the reasons why a simulation program is needed to help the improving process. There are key learning points, which need to covered before the start of the simulation project.

2.1 The process flow

In every part of the flow process of production can be transformed from inputs to output. The most important two keys objectives are evaluating and improving. Hence, we must keep tracing the transformation between inputs and outputs. There are five essential elements of a process, which we must understand first (Anupindi, 2004).

1. Inputs and outputs
2. Flow units
3. Network of activities and buffers
4. Resources
5. Information structure

Figure 2-1: The Process Flow (Anupindi, 2004)



1. Inputs and outputs. To understand all kinds of process in the world, we have to identify the inputs and outputs. Inputs refer to any tangible or intangible items that flow into the process from the environment. Inputs include raw materials, component parts, energy, data, and customers in need of service (Anaupindi wt al., 2004). For example, a customer is the input from the environment into a restaurant service. In another way, outputs are "any tangible or intangible items that flow from the process back into the environment, such as satisfied customers from restaurant". For example, satisfied customers leave from a restaurant to go back to the environment.

   From this point, inputs flow into the process, they are transformed, and leave the process as outputs. There is also information, such as purchase orders or bills, which flow back to the upstream process.

2. To understand more about the process, we have to realize what the flow unit is. Flow units can be a unit of input, such as a purchase order, or a unit of output, such as a satisfied customer. Moreover, a flow unit may also be the financial value of an input or output.

3. The most important part, which can also be a waste or add value to the process, is the network of activities and buffers. This stage can be divided into two. First, an activity is "the simplest form of transformation; it is the building block of a process" (Anupin di et al., 2004, p4). The second is a buffer which is "the flow units that finished with one activity but are waiting for the next activity to start."

   In term of production processes, storage is called inventory, which means the total number of flow units that flow within the production process. There might be precedence relationships among activities – the sequential relationships which concern the priority to be finished in each job.

4. Resources is the fourth element of the process. It conaiata of both using capital and labor resources. Capital resources mean tangible assets such as machines, equipment, or information systems. Labor resources are people who operate within the process, such as operators and staffs.

5. The last element is an information structure. It shows what kind of information is necessary and available to make right decisions for process management.

2.2 The 7 Wastes in a Production Process (Tapping, 2002)

In this topic, we have to realize what are the wastes costs to a company. Also, how can we reduce them? To eliminate waste is the key success of lean manufacturing. Wastes can also be time of waiting, inventory (WIP), over-processing or digital waste. And with these wastes, people in the production department have to work together to eliminate waste in production processes or even inventory keeping along the chain. Tapping said "waste is everything that is unnecessary". This meaning illustrates that there are only two or three things which will not to be eliminated and it is called "Work". Work means the activity that creates the value to the product. Shigeo Shingo has identified the 7 deadly wastes usually found in the factory.

1. Overproduction: Production of product, which does not meet customer demand or exceeds the demand.

2. Inventory: Raw material, work-in-process, and finished goods.

3. Transportation: To move the product within internal processes.

4. Defects: Under quality part or product, which can impact on lower productivity and stop the flow of quality products.

5. Processes : Necessary work

6. Operations : Every activity, which does not add value to the product.

7. Inactivities : Idle machine or labor.

In conclusion, inventory is the most dangerous waste. Moreover, inventory is the sign of a sick factory because it hides other problems which cannot be found to be eliminated.

2.3 About Simulation

2.3.1 Definitions and concepts (Carson, 2005)

There are many kinds of simulation. At first, this is limited to discrete-event, process-oriented simulation. This contains almost all simulations discussed at the Winter Simulation Conference. It does not include Monte Carlo-type simulations in a spreadsheet . It also excludes equation-based numerical solvers, such as differential equation solvers and other equation involved models.

2.3.2 A use of simulation.

A simulation model is an illustrative model of a process or system, and also includes parameters that empower the model to be configurable to describe a number of some different systems or process configurations. Easy examples include parameters that allow a user to adjust the number of staffs or workers at a workstation, the speed of a machine or vehicle, the length of a conveyor control system, and so on. As a current state model, a simulation model can be used to observe and evaluate and compare any number of parameters in the system. Evaluation, comparison and analysis are the key points for working with simulation. Expectation of system performance and identification of model problems and their causes are the key results.

2.3.3 Situations for using simulation

Simulation is most beneficial in the following situations:

1. There is no simple logical model because a spreadsheet model calculation is not enough to accurately analyze the model situation.
2. The system is regularized. So, it is not confused and out of control. System parameters can be identified and characterized and also their defined interaction.
3. The system has some level of complexity, interaction between various components, or pure size that makes it difficult to understand it overall. Moreover, it is difficult or impossible to forecast the effect of parameters changes.
4. Designing a new system, examining major changes in physical layout or operating policy in an existing system, or being confronted with new and different demand.
5. Considering a large capital investment in a new or existing system which describes a system modification of a type of which you have poor or no experience and also face considerable risk.
6. Want to have a tool which all the people involved can accept on a set of assumptions, and see (both statistically and with animation) the simulation results and effects of the assumptions. Hence, a simulation process as good as the simulation model can be used to bring all members of a team to a common understanding.

7. Simulation with animation is a very excellent training and educational material, for all people in the system such as; managers, supervisors, engineers and labor. Moreover, in systems of large scale, the simulation animation might be the only method by which most participants can visualize how their work shares in the overall system success or identifies problems for others.

2.3.4 Conclusion about the benefits of simulation optimization

According a paper by Glover and Fu (2005), the simulation volume is explained. More technical details on simulation optimization techniques can be found in the chapter by Andradóttir (1998) and the review paper by Fu (1994). The feature article by Fu (2002) explores deeper research and practical issues. Previous volumes of these Winter Simulation Conference proceedings also explain good current sources (e.g., April et al. 2003, 2004). Other books that use simulation optimization in some technical depth include Rubinstein and Shapiro (1993), Fu and Hu (1997), Pflug (1997), and Spall (2003).

This research has been created in a multi-response simulation optimization where the constraints must be estimated. However, most of the commercial software packages authorize multiple responses and exact adjusted constraints on output performance measures. To summarize, there are some key points in simulation optimization algorithms:

- Neighborhood definition.
- Mechanism for exploration, especially how previously generated sample solutions are incorporated.
- Determining which solutions to accept as the best statistical statements.
- The computational obstacle of each components estimate obtained through simulation replications relative to finding out the optimization algorithm.

2.4 Cellular Manufacturing

In term of a production flow system, products must not be grouped separately. The machine will be laid out in order to reduce the waste time of transportation and to support the flow system. (Tapping and Luyster, 2002)

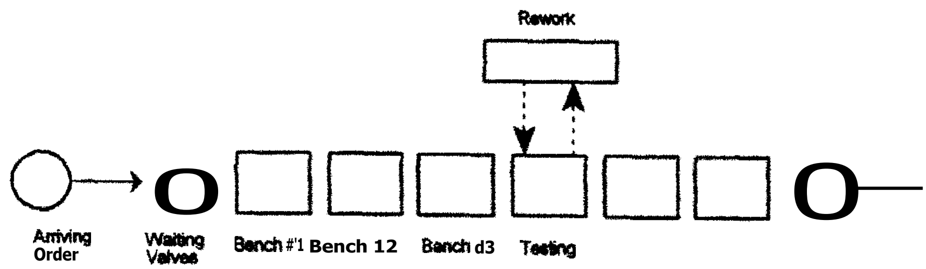
Work cell is one of the methods to help the operation flow. It works as the station to integrate all work. In other words it arranges the machine and operator in a production process and integrates the operation to complete the process productively. Hence the operation arranges the production process to ensure that the work is produced with the best quality and least waste. The importance of work cell layout instruction consists of these elements:

1. Respectively arrange.
2. Build up work cells counter- clockwise for the better use of the right hand side.
3. Put the machine close to another while considering safety.
4. Set the last work station close to the beginning point.
5. Build cells in U-shape or C-shape or L-shaped according to the limitations of environment.

One company showing a continuous flow of self managed work team is Hamilton Standard, described in (Sammon and Cochran, 1996). The firm produces aircraft products for commercial and military use from the raw material through to the finished good in the customer's hand.

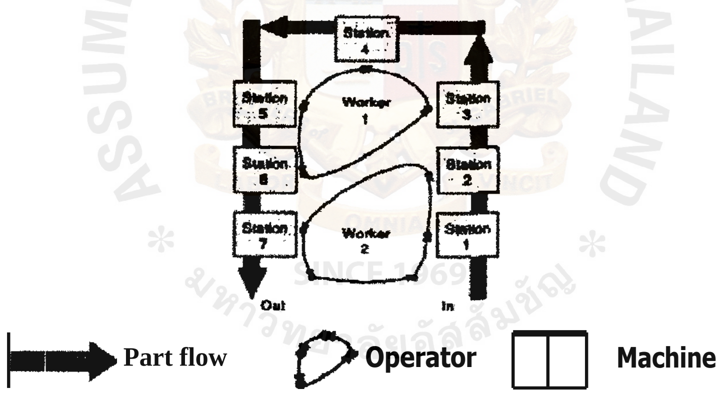
A work cell is designed by people and equipment from their functional areas, placing them in the same work place to reduce movement distances and letting the product flow from one bench to another. Figure 2.2 shows a chart of the layout and the product flow for the work cell.

Figure 2.2 : Schematic Diagram of Assembly and Testing Stations



Moreover, Cochran and Taj (1998) said that a lean cellular manufacturing system could improve both quality and get rid of wastes together with their costs. A lean cell (shown in Figure 2-3) would have all machine processes as part flow of a single-piece between operation and operators. Thus all those defects would be eliminated before the operation proceeds.

Figure 2-3 : Lean Manufacturing Cell



2.4.1 The link between cellular manufacturing and simulation

Standridge and Mass (2005) said that the most potential part of the lean method is to reduce the simulation parts in the application area (Harit 2005). As such, the manufacturing of plastic products has used the application of simulation in order to aid the design. The software is used to analyze the capacity in order to enable customer orders of products and get good simulation results. The simulations and other analysis results can assess cell performance together with customer service and the management target; inventory levels versus the management specified target, inventory levels versus predetermined target levels, and station utilization. Alternative assignment of product families to workstations were compared.

2.5 Optimal batch size

Next, New (1972) created a new approach to the setting of optimal batch sizes and production lead times, and illustrates how both are constructed together in relation to the work-load in the shop. Moreover, this paper works on the simulation studies of a 75-machine job shop in which the use of decision rules resulted in considerable improvement over the existing practice. The system is particularly applicable in situations where it is not feasible to use work-sequencing systems on each individual machine groups, when it works by the control of input times only. Although the overall improvement was tested using simulation methods, all data are realistic and relate to the specific shop in which it was designed.

According to Gregory (1983), an attempt has been made to enhance small batch-manufacturing firms by material ordering and production scheduling practices. Four objectives of classifications of small batch manufacturers were explained with their corresponding parameters of relation. Outlines of decision-making policies were proposed.

In 1994, Sarker and Parija reported in their paper improvements in ordering policy for raw materials to acquire the targets of a production facility which must deliver finished goods demanded by external buyers. First, a general cost model is constructed by considering both supplier of raw material and buyer of finished goods. Then, the model is used to determine an optimal ordering batch size policy for procurement of raw materials, and the manufacturing batch size to minimize the total cost for meeting equal shipments of the finished products, at fixed intervals, to the purchaser. An interval that contains the best optimal solution is first judged, followed by an optimization technique to investigate the exact solution from this interval.

Rose (2006) explained the implications which followed from small lot-sizes for tool models used for the appraisal. The critical constraint is that short cycle times are the success of semiconductor manufacturing. More chip mask layers leads to higher raw process times and makes short cycle times an increasingly obstructing task. One method of cycle time reduction, semiconductor manufacturers should look at is lot-size reduction. Also, the reduction in lot-size directly impacts on lower production times. Modeling and simulation are keys to assess opportunities of such an approach.

2.6 Validation Techniques (Sargent, 2008)

There are many validation techniques and tests in medal verification and validation . It can be used both subjectively and objectively. The word objectively means using some types of mathematical procedure or statistical test. These techniques are used to test both verification and validation of the sub-models and overall model. However, in this project we are concerned only with three validation techniques, which are :

2.6.1 Animation

The model's operation is displayed graphically as the model moves along the time. For example the movements of parts through a production line during a simulation run are shown graphically.

2.6.3 Historical Data Validation

When we have historical data, for example, data collected on a system specifically for building and testing a model, part of the data can be used to build up the simulation model, and the remaining data are used to determine whether the model behaves as the system does. This testing is conducted by driving the simulation model with either sample from distributions (Balci andSargent, 1982, 1982, 1984).

2.6.4 Parameter Variability - Sensitivity Analysis

This technique consists of changing the values of the input and internal parameters of a model to determine the effect upon the model's output. The same changing of relationships should happen in the model as in the real system. However, those parameters that are sensitive to significant changes in the model's behavior or output, should be made sufficiently accurate before being used in the model.

CHAPTER III

RESEARCH METHODOLOGY

An understanding gained from the first two chapters is that this project contains so many constraints and distribution of data, which can impact on project improvement. For example, how can we know the bad impact on other KPI if we reduce WIP in the production process from 400 sets to 100? Or, what it going to be negative if we implement more machines with failures? For these reasons, it is good to use only a simple calculation in Excel, without being concerned about other impacts, which will be sufficient for our objectives.

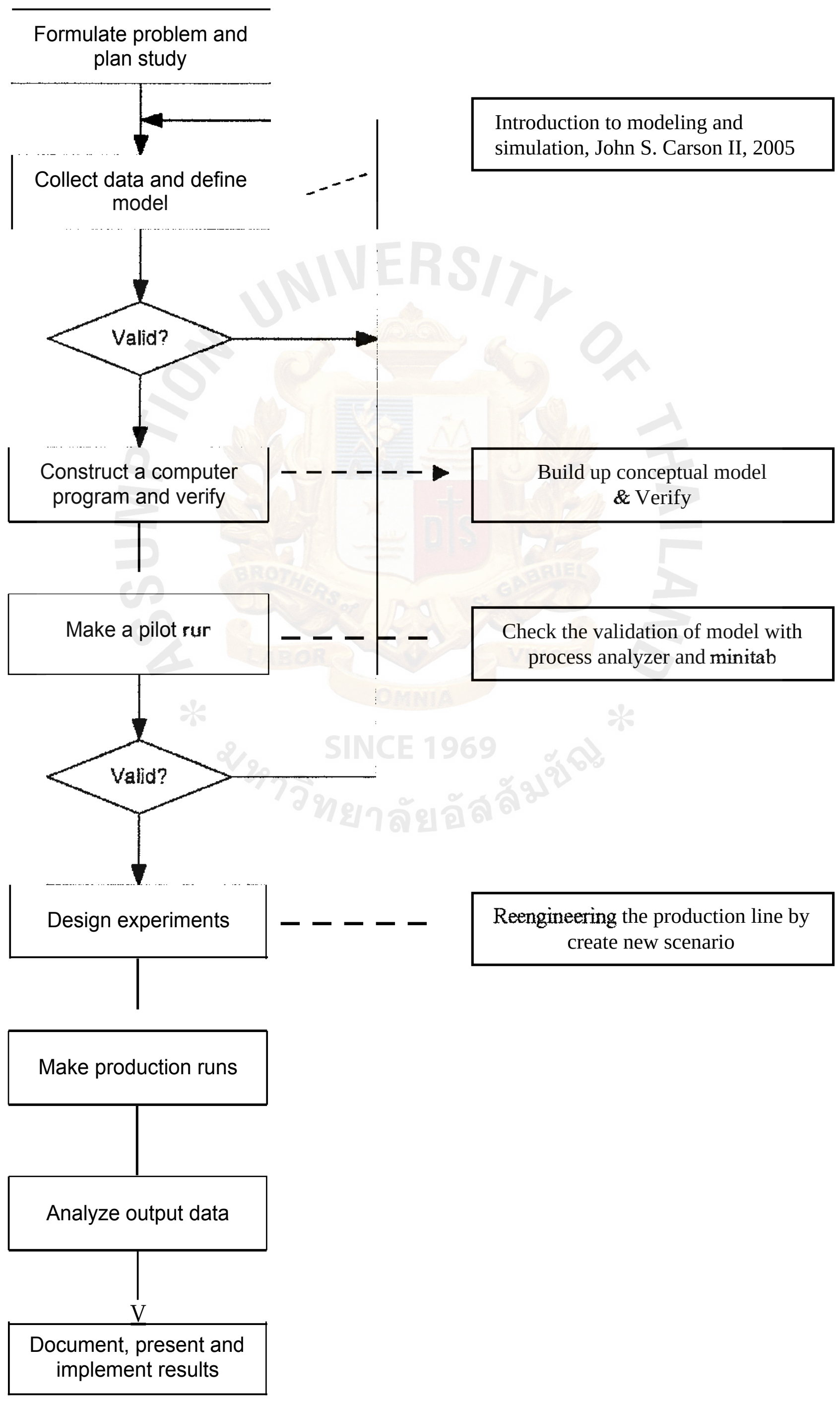
However, this reengineering project can be solved by using simulation because of three mains reasons. First, it can reduce the time needed for improvement. Second, simulation actually produces a highly accurate result. Finally, we can avoid risks from actually implementing change in the production line, which cannot be stopped for a trial run.

The research methodology clearly involves problem solving, with detailed presentations, for example, systems modeling, valid, credible and appropriately detailed model building. The generated random numbers and statistical techniques are also included. The book published Law and Kelton (2000) is highly recommended for those new practitioners who seek information about those simulation fields.

To define the problem described as step1, Figure 3.1 is shown to define the problem formulation; in other words it is concerned about the objectives of the study together with the assessment of the resources. In Step 2 data is collected and the model identified. Step 3 is to validate the data through the conceptual model. Step 4 constructs the computer model based on a conceptual model of the production system. In Step 5, the pilot run is constructed. In Step 6 the verification and validation will be made. Steps 7 to 10 cover the design of the experimentation. Step 11 is the document, presentation together with the implementation. Finally, the last part is about the analysis method and result together with the conclusion.

Figure 3-1: An Approach to simulation

Source : Adapted from Law and Kelton (2000)



3.1 Formulate the problem and plan of study

3.1.1 Project Initiations

This section states a meeting, problem formulation, objectives setting, determination of performance measurement, and details of modeling assumptions and data requirements, together with a project plan. Inside, the project line and cost estimates together with project timelines will be examined. Finally, the assumption document and a project plan will be covered.

3.1.2 Problem Formulation and Objectives Setting

The objectives of all modeling activities need to be communicated so that the problems may be initiated. The project team must clarify the problem by listing all specific questions needed to be studied. At the same time the evaluation must be set to measure whether or not the performance is set. Customers also play an important role in making this goal because of its achievement. In other words, the system is designed for setting the expected objectives. Hence the simulation analyst will put questions to all the people concerned, to establish working assumptions.

- Model boundary and scope,
- Level of detail,
- Project scope,

Model boundary means the scope that determines what is in and out of the model. Together we need to see the level and depth of the model. Questions and data availability will be asked and collected. The scope of the project with a specific conceptual model needs to be studied in order to avoid a project with no end. To do that we need to look at the production process? It is important to look into the big picture of all processes in order to find the many problems which occur during the production process.

Step 1: Overview of the Production Process

It is important to look in to the big picture of the overall process (Figure 3.4). Many of the problems occur along the production process. But it is hard to identify that.

In this step, we set up an improvement project meeting for the electric fan production department and conclude an agreement together to answer the question "What should we improve first and step by step?" A useful tool, again, is value stream mapping. We have a little depth in detail to look into the motor production line, as in Figure 3-4, which is the most upstream for electric fan production. The reason is if we can improve the problems for the upstream of the production line, it can be better impact other problems downstream also. Hence, in the first step, scope the simulation model is applied to the motor line only. Then in the second step, the motor line is linked with the fan assembly line to synchronize the work and see the overall result together.

Figure 3-2: Plant layout for motor production group 16 B

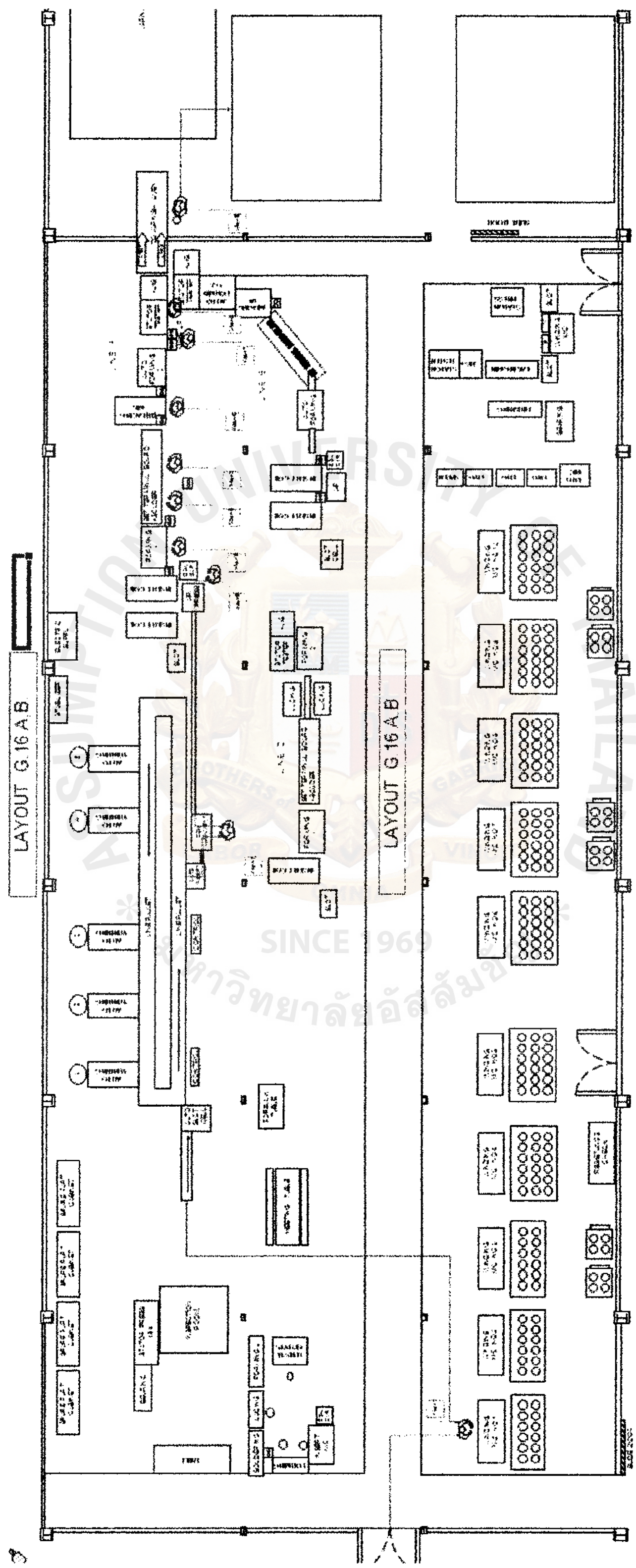
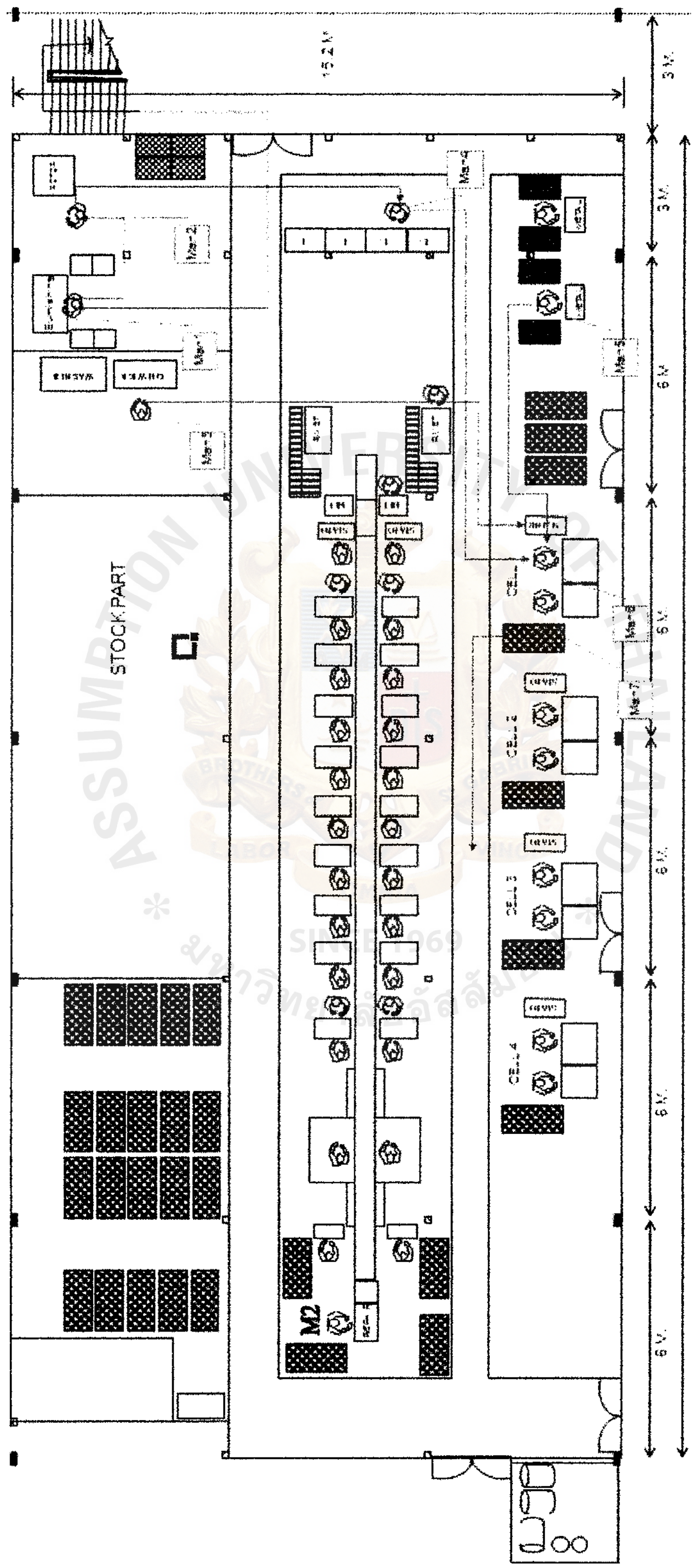
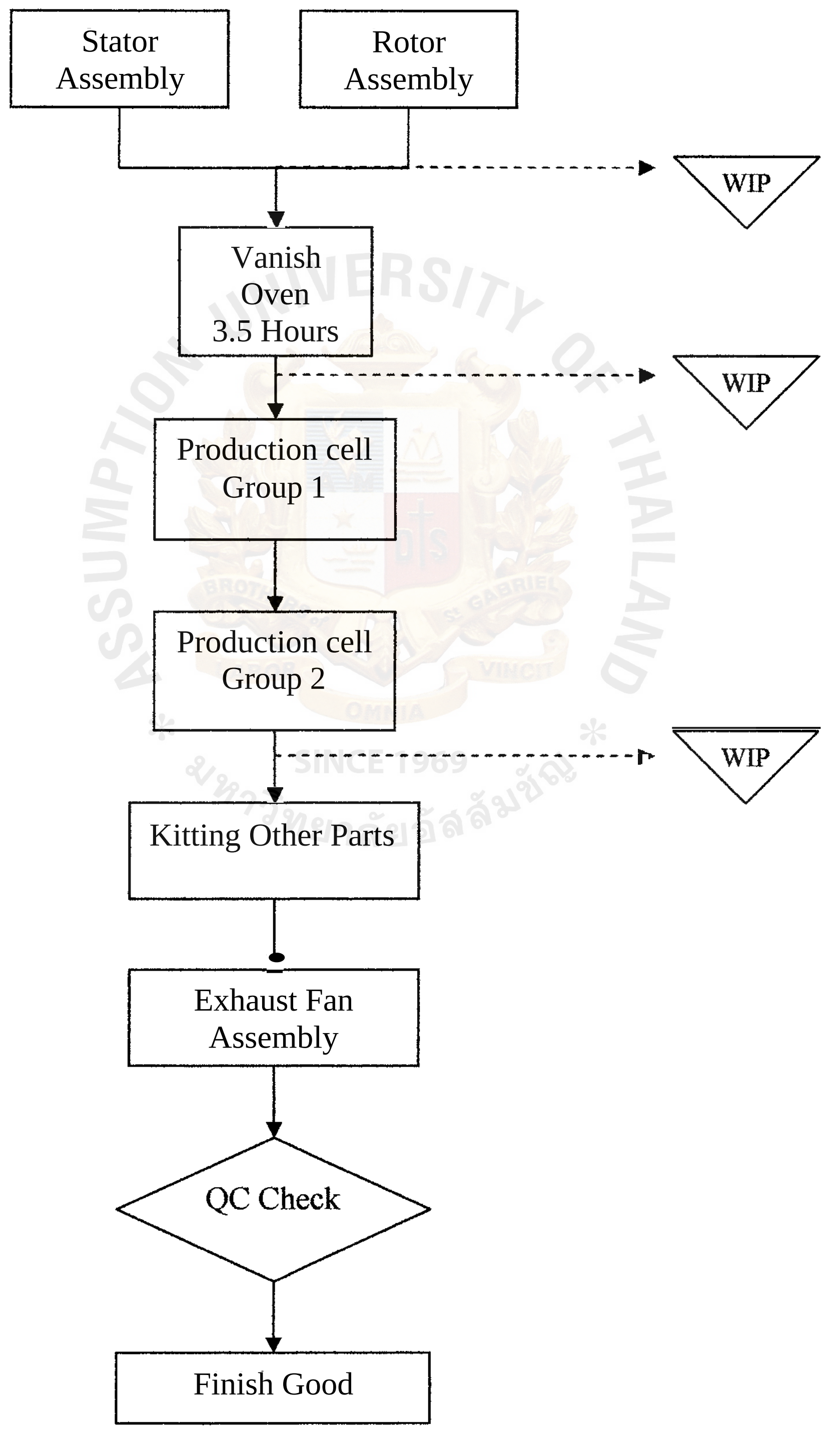


Figure 3-3: Plant layout for motor production group 16 C



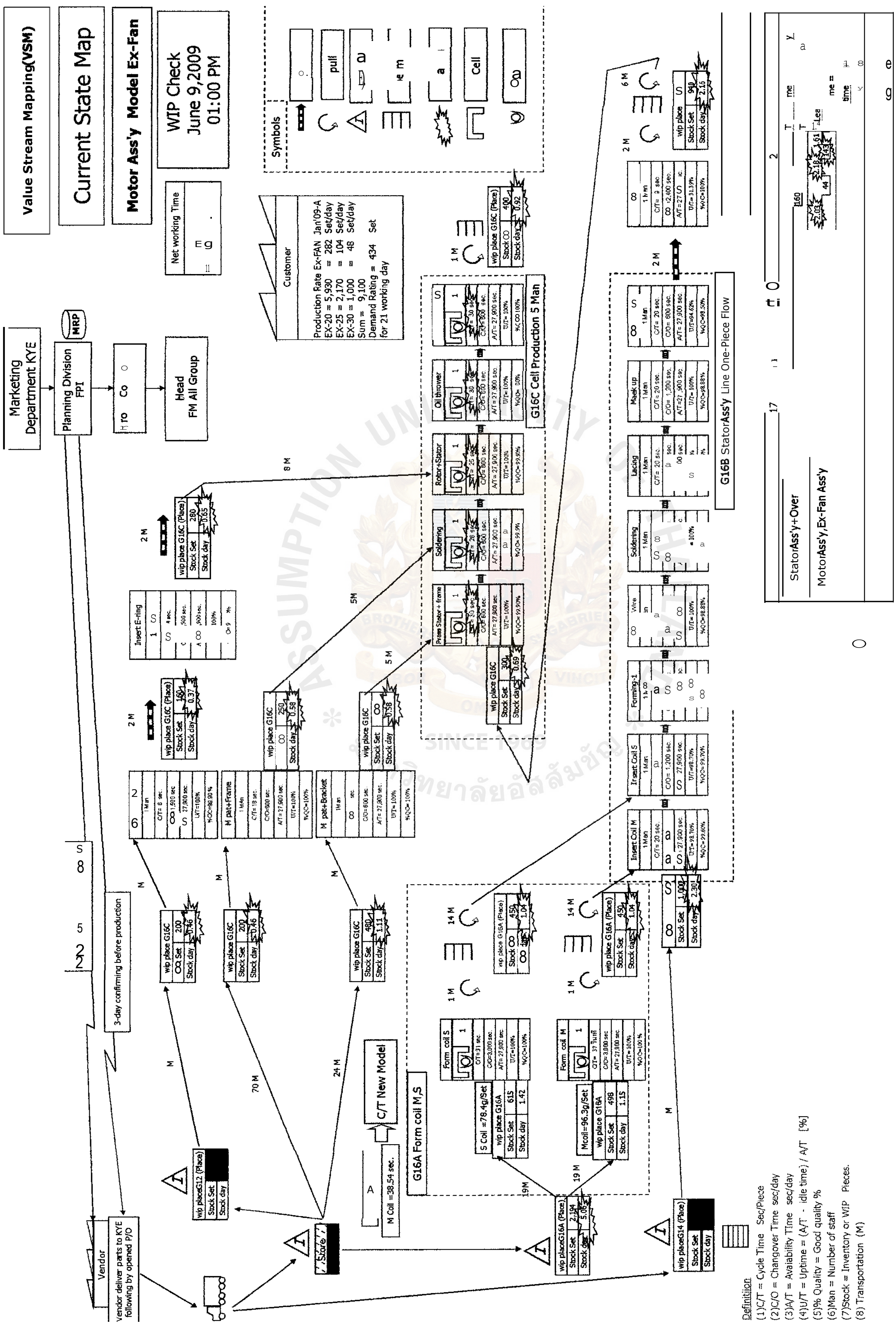
After we design the product flow diagram and details of every process, we can capture the work-in-process, found in every workstation and cause problems to the overall process

Figure 3.4: Overview of the production process



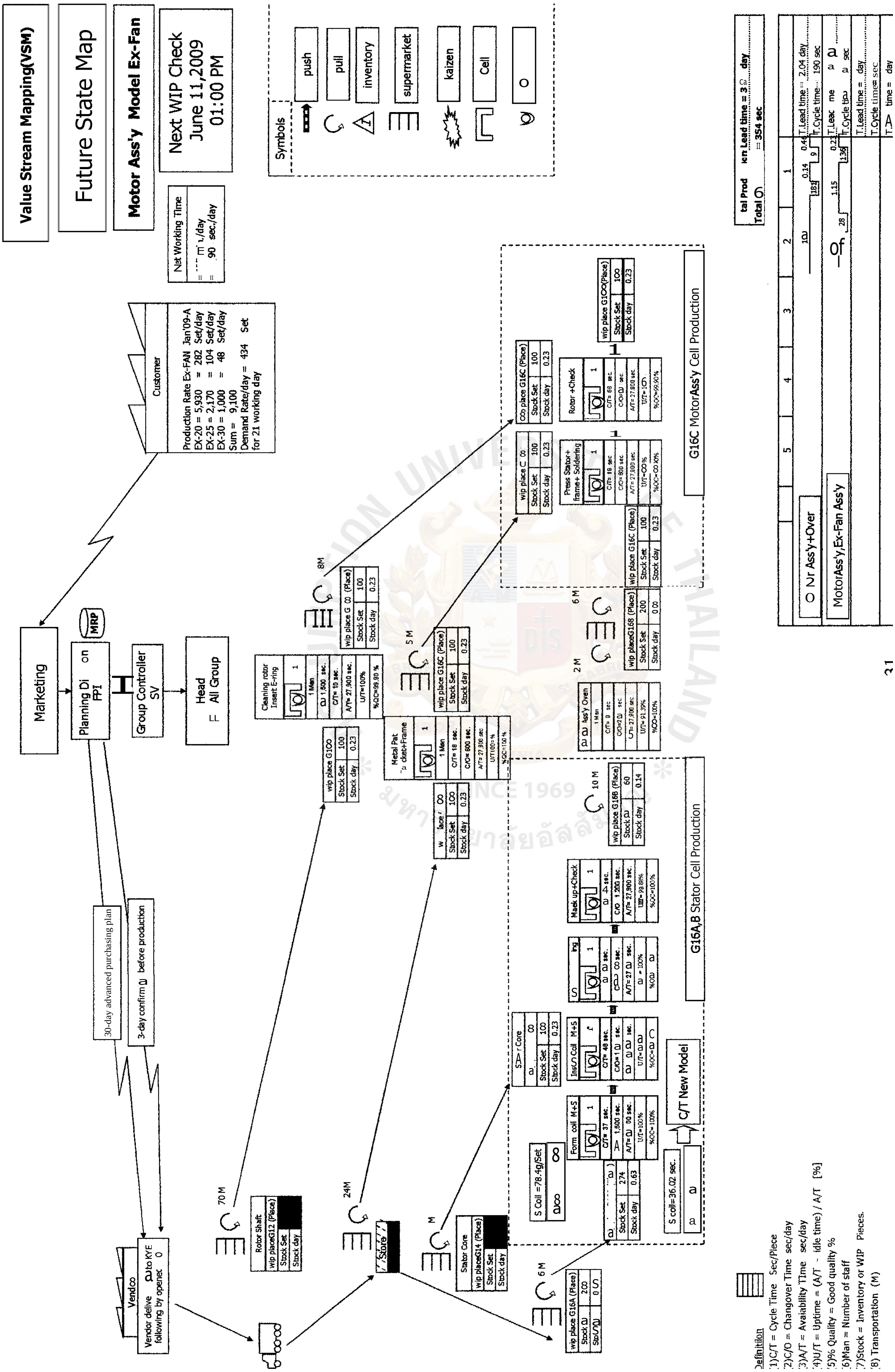
Step 2: Capture the problem with value stream mapping (As-is)

Figure 3-3: As-is **VSM**



Step 3: Redesign the production process with value stream mapping (To-be)

<u>Figure 3-4:</u> As-is **VSM**



From Figure 3.6 (as-is), we can see the long lead time 19.99 days for stator assembly with conveyor line assembly. It causes work in process 940 pieces after oven and varnishing process, which is 2.16 days. In contrast, in Figure 3-4, we try to figure out this problem by changing the conveyor line to group cell. The point is to reduce lead time, especially for wastes, from 19.99 days to 3.88 days or equal to a reduction of 80.59%.

However, in the simulation model we have to cut off the outbound production line and the purchasing part from the actual production line, in which the lead time of only the inbound production line equals 3.41 days. So, we can use this lead time to be the current state model in the next step.

The Conclusion of conceptual (current state) model boundary and scope

Table 3.1: Simulation Boundary

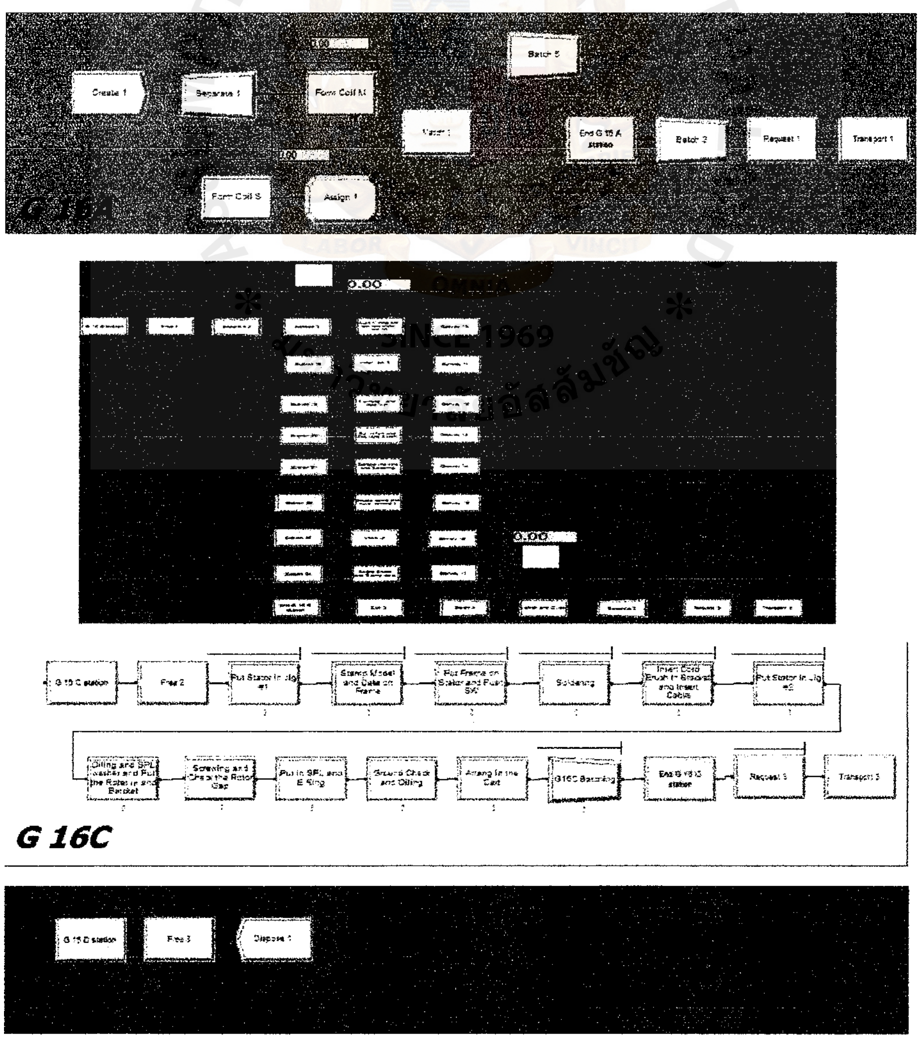
Details	Value
Product Type	Fan
Production line	Inbound Motor
Assemble Line	Exhaust fan
Simulation Length	21 days
Simulation Program	ARENA
Simulation Measurement	Second

3.1.3 Conceptual Model and Assumptions Document

The conceptual model is the set of understandings, assumptions, and data. These assumptions and data requirements should be made in detail in an Assumptions Document or Functional Specifications Document. The Assumptions Document should be written in the language of the real system and the people who work in that system. It is important that the language used should achieve its purpose to communicate a set of assumptions and data requirements among all members of the simulation team who will need to be simulation experts. Then the teams re-define the assumption until all members agree to work on the assumption.

Firstly, get all interested parties involved in the project start in order to sort out all model assumptions by discussion. If anyone disagrees with the assumption it needs to be cleared at this stage. If the person gets queries they must input the questions on the table at the project stage. Secondly, put all assumptions and data requirements into written statements, including objectives, address specific questions, and system performance measurement. The written assumptions documents is essential. A reviewed, and signed-off, assumptions Document is critical.

Build up conceptual simulation model



3.2 Data Collection, Cleansing and Analysis

KYE works by collecting the agreed-upon data. If data is not sufficient or uses estimation, then we should discuss these data assumptions among the knowledgeable people involved in the processes.

Sources of data include databases, manual records, automatic data collection systems, sampling studies and time studies. Unfortunately, it seldom happens that all or even much of the needed data is readily available, or that the accessible data would meet the desired quality. In these circumstances, much effort and expense may be required to collect the data or extract it from existing databases.

After collection, a further effort may be required to validate and "cleanse" the data. Even the data in KYE databases, surprisingly to some, may be suspect. Often simple tests or audits may show that what appears to be data availability is data garbage.

In this project, there are six categories of data of interest.

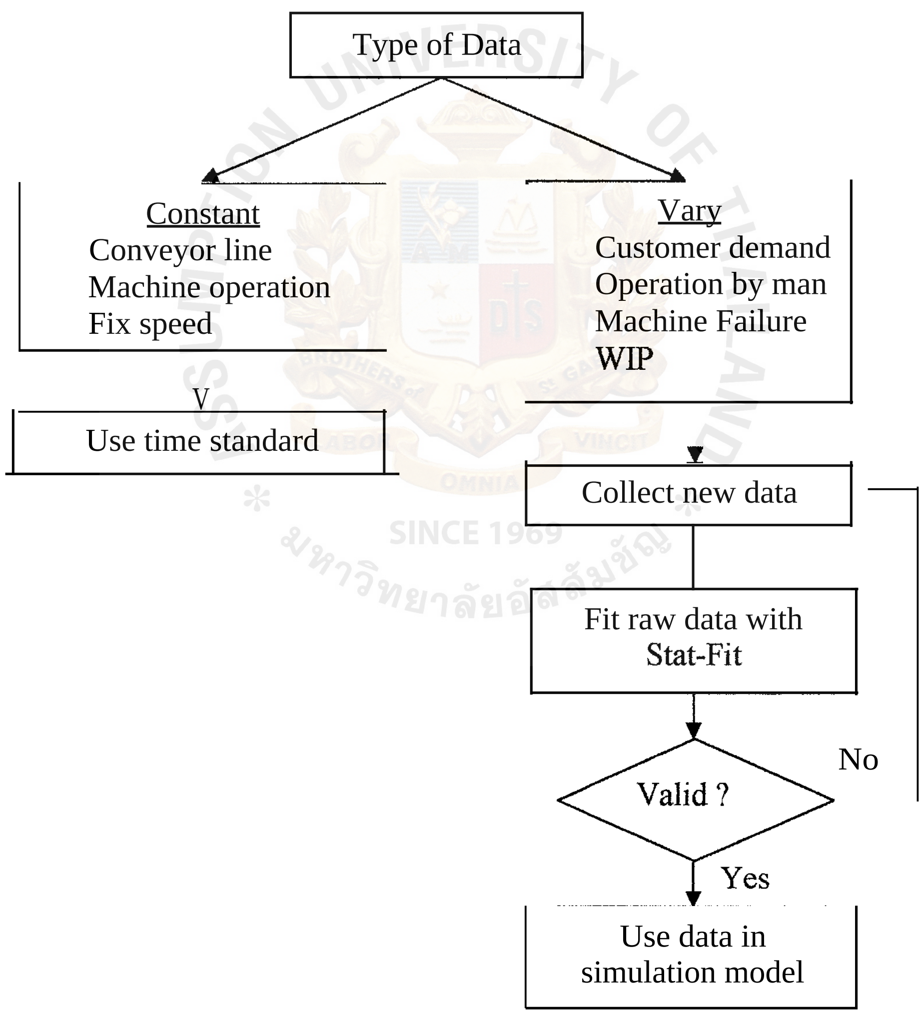
1. Production process flow diagram
2. Resources including machine and operator
3. Process time
4. Change over and setup time
5. Work-in-process at each workstation

Step 1 **:** Understanding Type of Data

We can divide the type of production data in 2 main categories.

1. Constant Data comes from conveyor line.
2. Variable Data happens because of people, such as in cellular motor assembly.

Figure 3.7: Type of data



Type 1: The Constant Data

Process time depends on the conveyor line

Table 3.2: Standard time of motor production process

Time standard of Motor **Assemby** Model **EX-20SH3T**

Group	Man	Process	Time (sec)	Type of data	Type of production
G.16A	1	1.FORM COIL S (1,000T*4)	32	Constant with standard	Conveyor
		2.FORM COIL M(1,160T*4)	36		
G.16B	1	1. Auto winding + Auto slot & coil M	19		
	2	2. Coil insert-S	18		
	3	3. Forming-1 + Pes Flim	19		
	4	4. Film + Pes tape 2 Point	19		
	5	5. Terminal + Soldering	17		
	6	6.Double lacing + Auto forming – 2	19		
	7	7.Make up	19		
	8	8.Scope check ,Stamp date	19		
	9	9.VARNISH+OVEN	8		
G.16C	1	1. Burnishing Rotor Shaft Assembly	8	Constant with standard	Out Line
	2	2. Cleansing Rotor Shaft	6		
	3	3. DROP OIL WICK(M/C)	3		
	4	4. INSERT E-RING	2		
	5	5. PRESS METAL PAT Bracket	15		
		6. PRESS METAL PAT Frame	16		
	6	7. Put Stator into Jig	4	Vary	Group Cell
		8.Stamp Model & Date on Frame	7		
		9. Put Frame on Stator + Push SW.	2		
		10. Soldering	42		
		11. Cord Bush & BRACKET	12		
	7	12. Put Stator into Jig	2		

		13. Oiling Rotor Shaft + SPL Washer + Rotor Shaft into Stator	10		
		14. Screwing + Checking Gap	15		
		15. Put SPL + E-Ring	15	Vary	Group Cell
		16. Insert electric cord	9		
		17. Put motor into a cart	3		
G.16D	1	Packing screw	21	Constant with standard	Out Line
	2	Stamp Model	3		
	3	Packing Instruction Sheet	3		
	4	Assembly capacitor with connector	27		
			452		

Type 2: The Variable data

1. Production plan of fan motor : Two days per one order

Table 3.3: Production plan of motor

Day	May	Jun	July
1	900	850	970
2	1000	910	900
3	1080	840	1000
4	1160	900	890
5	800	1000	650
6	845	980	800
7	800	900	850
8	720	870	840
9	600	800	900
10	870	750	780
11	900	920	920
12	950	840	900
13	780	890	870
14	840	800	970
15	940	900	1000
16	860	700	840

Distribution Summary

Distribution: Normal

Expression: NORM(874, 101)

Square Error: 0.006021

2. Production lead time of group cell (work by operator)

Time: 8.00 – 12.00

<u>Table 3.4:</u> Production lead time for group cell 1 and 2 for morning

Process	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	5.35	5.05	5.46	4.46	4.48	4.94	5.34	4.32	6.4	4.96
2	5.83	5.14	5.1	5.3	5.32	5.29	6.05	5.61	6.15	5.04
3	2.26	1.99	2.26	2.46	2.16	2.41	2.74	2.28	2.07	4.51
4	40.46	24.32	26.96	34.38	28.8	29.58	38.9	31.67	37.62	28.21
5	7.82	8.17	10.69	15.05	12.16	8.98	9.57	8.62	8.21	11.84
6	3.83	3.38	3.39	3.9	2.97	4.34	3.53	3.39	3.09	3.14
7	16.97	22.9	19.45	18.98	46.84	18.25	17.73	19.98	15.94	24.09
8	11.46	13	14.24	13.06	12.69	13.15	13.4	12.22	15.5	14.21
9	6.68	7.88	6.39	7.07	9	7.64	7	6.96	7.87	11.08
10	9.76	10.02	9.95	11.02	13.75	10.28	15.45	10.18	11.73	10.65
11	3.66	2.9	2.39	2.4	2.59	2.26	2.66	2.24	2.37	2.41

Time: 13.00 -16.00

<u>Table 3.5:</u> Production lead time for group cell 1 and 2 for noon

Process	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	4.41	6.57	4.3	5.55	4.76	4.34	4.55	4.53	6.54	3.89
2	7.23	8.75	6.08	5.54	6.66	5.57	4.94	6.29	4.94	4.81
3	2.48	2.28	2.15	2.59	2.44	2.3	2.65	3.38	2.35	2.12
4	31.88	28.51	29.69	41.86	37.88	31.55	35.93	46.43	34.66	31.02
5	10.16	12.6	15.65	8.82	8.19	15.25	8.96	10.26	11.03	10.58
6	2.81	3.06	2.53	3.7	3.67	3.32	3.55	4.17	2.64	2.78
7	21.23	41.87	17.88	17.08	30.62	24.12	16.28	34.07	35.47	18.76
8	13.21	13.23	14.61	14.3	13.59	14.47	12.42	15.99	12.33	15.18
9	9.29	6.68	7.92	8.49	7.91	10.25	7.57	7.27	7.36	9.61
10	10.82	14.45	9.98	10.6	10.69	16.33	14.08	11.61	12.03	15.38
11	2.4	2.77	2.28	2.27	2.17	3.16	3.19	2.41	1.81	2.02

Table 3.6: Distribution Summary For G 16 C Process Time

Process	Distribution	Expression
1	Lognormal	3.43 + LOGN(1.75, 0.859)
2	Lognormal	4 + LOGN(1.91, 0.965)
3	Lognormal	1.27 + LOGN(1.32, 0.616)
4	Gamma	24 + GAMM(4.03, 2.05)
5	Gamma	6 + GAMM(1.15, 4.15)
6	Lognormal	2.34 + LOGN(0.92, 0.46)
7	Lognormal	15 + LOGN(7.76, 9.26)
8	Lognormal	11 + LOGN(3.17, 2.03)
9	Lognormal	5.06 + LOGN(2.64, 1.33)
10	Lognormal	9 + LOGN(2.7, 2.34)
11	Gamma	1.42 + GAMM(0.158,6.31)

3. Work in process at specific workstation

Table 3.7: Work-in-process in every workstation

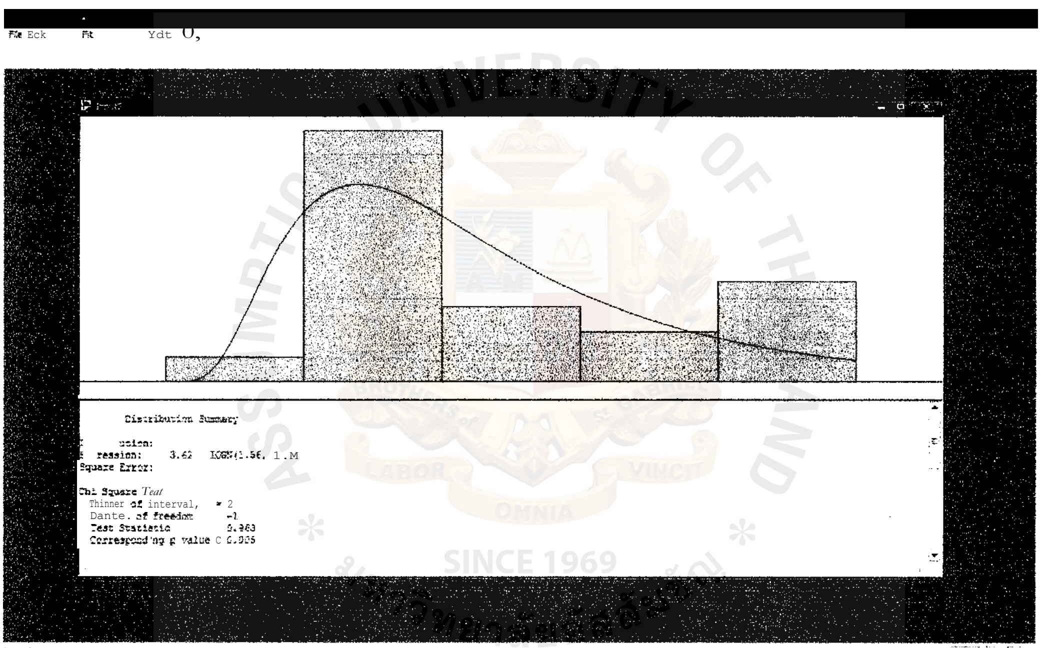
Check WIP Motor Assembly EX-Fan
(all)

				Time				
Incharge	Check WIP		Unit	8:00	10:00	12:00	14:00	16:00
G.16A	1	Mat'! Coil M, S	(reel)	200	200	200	200	200
	3	Coil S (FG + Insert Coil G.16B)	(set)	310	300	300	300	300
G.16B	4	Forming 2	(set)	20	6	-	3	10
	5	Make up	(set)	14	4	2	4	6
	6	Check Scope	(set)	36	140	10	90	76
	7	Varnish Oven	(set)	351	351	351	238	342
G.16C	8	Stator Man1	(set)	300	190	151	350	270

Step 2: Example for fitting the raw data with input analyzer program

4.37	6.2	5.23	5.81	4.67
6.26	4.72	5.99	4.83	5.41
4.41	6.57	4.3	5.55	4.76
4.34	4.55	4.53	6.54	3.89

Figure 3.8: Fitting set of raw data to distribution



After fitting the raw data into the input analyzer program we can get the distribution type of set of data. It can be seen in the detail whether the set of data is significant or not by look at the corresponding p-value. If p-value < 0.05, it shows that the error of distribution data that to be put into the simulation model does not have an error of more that 5%, and that is acceptable for use as input for the conceptual model.

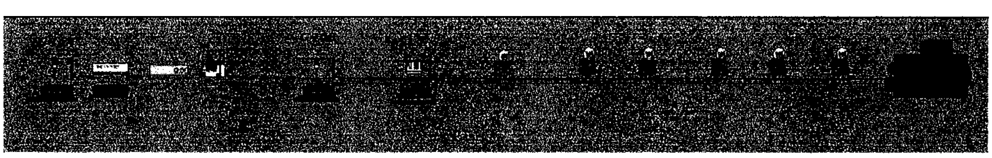
3.3 Model Verification and Validation

At this point the simulation analyst verifies the model, works with the customer and validates the model. If problems occur, either the model or the data are corrected. The end result of the verified and validated model, or V&V phase, is judged to be accurate enough for experimentation purposes over the range of system designs contemplated.

3.3.1 Model Verification

In the model verification, we plan to check the model by using a number of different techniques to verify that the running model accords with the Assumptions Document. This is more than debugging only a the programming. All model outputs should be valid and be reasonable over a range of the input parameters. Various techniques should be applied, including but not limited to: (1) stress testing with a wide range of parameters and different distribution numbers; (2) a overall review of all model outputs, not only the first measures of performance, but various secondary measures; (3) using the software's debugger, animation and other tools provided; (4) using selective traces, especially for complex parameters of the logic; and (5) review by a more senior simulation professional such as our professor (especially valuable for relatively new practitioners).

Figure 3.9: Example for verifying current state model with animation



3.3.2 Model Validation

Model validation gets the KYE staff involved. After the simulation team agree that the model is accurate and verified, this report will conduct an overall model review with the KYE staff. It is important to have all members of the customer team who may have an interest or "investment" in the model, and who expect the model to answer their questions. If a team member is present at meetings to present the model results, that team member should be present at validation review meetings and, indeed, at earlier project kickoff meetings. Various techniques, similar to those used during verification, may be used along with model validation, including.

1. Use of animations and other visual displays to communicate model assumptions.
2. Output performance measurement for a model configuration representing an existing system or an initial design, so that team members may judge model reasonableness. If sufficient data has been collected on other simulation model systems that matches one of the model's possible configurations, more formal tests may be conducted comparing the real system to the model. For more discussion of V&V, see Carson (2002). In addition, a subsequent talk on model verification and validation in the introductory tutorial track will provide more detail on appropriate techniques and issues. However, this project validates with real current state situation, and the tolerance of validation can be accepted with +10% to -10% errors after meeting with the production manager and experts.

3.3.2.1 Validation of simulation model

Before we start analyzing the result from the simulation model, we need to work on validating the model first. Four criteria used for validating the model are :

1. Cycle time from each production group and also overall process
2. Lead time from overall process
3. Throughput from the final finished goods
4. Work in process at critical work stations

Validation of production Cycle time

Table 3.8: Validation of production Cycle time for G 16 A and G 16 B

Production Group	Fix Cycle Time		
	Actual	Simulate	% Error
G 16 A	36.14 sec	36.14sec	0%
G 16 B	212.50 min	214.60 min	0.98%

Table 3.9: Validation of production Cycle time for G 16 C

Production Group	Variable Cycle Time (Second)			
	Actual Avg	Simulate		
		Min	Max	Avg
G 16 C	61	61.896	62.058	61.986

Validation of total production lead time

We have to clean up raw material purchasing data which is equal for 16.75 days because it is beyond the project scope

Table 3.10: Validation of total production lead time

Production Group	Lead time		
	Actual	Simulate	% Error
Overall	3.35 days	3.40 days	1.50%

Validation of throughput from the final finish goods

Table 3.11: Validation of Throughput from the final finish goods

Production Group	Throughput per day		
	Actual	Simulate	% Error
Overall	451	464	2.88%

Validation of work in process at critical work stations

Table 3.12: Validation of work in process at critical work stations

Work Station	Work in process (units) Average		
	Actual	Simulate	% Error
Material Coil	200	210	5.00%
Finish Coil	300	299	0.33%
Vanish and Oven	160	168	5.00%
Stator Assembly	600	617	2.83%

As we can see that for all acceptable (+10, -10) simulated data as we concluded in the project improvement team, we can perform the analysis result and plan for design of experiments in the next current state result.

3.4 Experimentation, Analysis and Reporting

The purpose of this phase is to meet initial project objectives: to evaluate and compare system performance, and to gain insight into the system's dynamic behavior and, in particular, into any problems or bottlenecks identified by the analysis.

3.4.1 Experimental Design

Before conducting simulation experiments, the analyst must decide a number of issues:

1. The input parameters to be varied, their range and legitimate combinations.
2. Model run length (how long to run the simulation)
3. For steady-state analyses, the model warm-up period
4. Number of statistical replications.

We should produce decision to the question in order to inform the experimentation. In earlier phases, we should check the range of model variability with an appropriate number of replications needed for further experiments. Model run-length may be stated by the current state of the system or the available data, such as when simulating one day's operation of a distribution center, where the data represents a fixed period of time. Other models with less inherent variability have needed only 3 to 5 replications. In other models, model run-length may be under the analyst's control. There is no rule for run-length or number of replications; each is model dependent. The number of replications affects the statistical accuracy of performance measures; specifically, it affects the range of confidence interval value. However, we should talk in the introductory phase about other statistical issues.

3.4.2 Experimentation

When the project plan developed we need a set of experiments. To compare the simulation model to other alternatives, sometimes we may evaluate other alternatives also. The model variations including the range of input parameters needs to be simulated. Questions may arise and may change the experiments. So each phrase of the experimentation should be guided by experiment design. Thus, the experiment may be used cleverly.

In Table 3.13, we try to give an example for design experiments, which conclude with cellular manufacturing, optimal production batch size, and reduced machine setup time. However, in actuality, we can investigate and design other scenarios from the result that we will receive from the current state model.

Table 3.13: Example of designing an experiment

Process Reengineering	Group 16 A		Group 16 B		Group 16 C		Production Batch Size		
	Details	Labor	Details	Labor	Details	Labor	G 16 A	G 16 B	G 16 C
Current state	Winding	2	Conveyor	9	Cell	2	900	450	450
Scenario # 1	Winding	2	Cell	4	Cell	2	900	450	450
Scenario # 2	Winding	2	Cell	3	Cell	2	900	450	450
Scenario # 3	Winding	1	Cell	3	Cell	2	900	450	450
Scenario # 4	Cell	1	Cell	3	Cell	2	900	0	450
Scenario 4 5	Cell	1	Cell	3	Cell	2	900	0	100
Scenario # 6	Cell	1	Cell	3	Cell	2	450	0	100

After finishing methodologies, we plan to build up the new simulation model to support our assumptions. The step is the same as trial and error. But, we have to identify reasons to accept the improvement result for each scenario. Then, we can keep the positive activity from the improved scenario to extend to other new scenarios.

However, we have to be concerned about the model boundary, which includes throughput per day, minimum number of manpower, and possible layout of machine.. Without these boundaries, we can lose to way to improve, or create an impossible improvement model, which cannot be used in reality.

CHAPTER IV

Result and Analysis

This chapter presents the simulation result from the current state model and also an analysis. It is necessary to confirm whether our simulation is valid or not. So, we test the model in term of average value of each major parameter and also a statistical test with non-parametric technique (see Appendix A for more details).

4.1 Simulation result and objective value

Production time and throughput

Table 4.1: Production time and throughput result

Production Time	Result
Cycle time	214 6 min
Lead time	3.40 days
Throughput /day	464 units

Work in process

Table 4.2: Work in process result

Work Station	Work in process (units)		
	Simulate	฿ / unit	Total
Material Coil	210	33.00	฿ 6,390
Finish Coil M &S	299	64.00	B 19,136
Vanish and Oven	164	99.00	฿ 16,236
Stator Assembly	617	105.00	฿ 64,785
Total	1,290		฿ 107,087

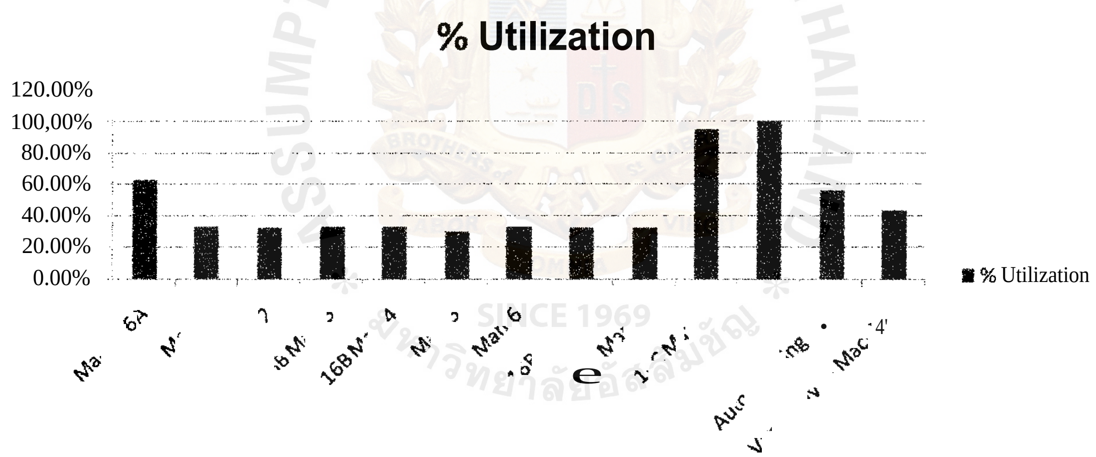
Resource Utilization

Table 4.3: Resource Utilization result

Resource	% Utilization
Man1 16A	62.74%
16B Man 1	33.02%

16B Man 2	32.09%
16B Man 3	33.27%
16B Man 4	33.27%
16B Man 5	30.15%
16B Man 6	33.27%
16B Man 7	32.34%
16B Man 8	32.15%
16C Man 6	95.44%
16C Man 7	100.00%
Auto Winding MC	56.37%
Varnish Oven Machine	43.75%

Figure 4.1: Resource utilization graph



Operation Cost

Operation cost = 19,571 per month (21 operation days)

It will be seen from the above chart that there is low utilization in some work stations. This is because KYE used to produce exhaust fans. After they finished producing exhaust fans, they change to another fan model. But there are changes over wastes which occur during the production day, and also a lot of WIP of exhaust fan.

However, this kind of situation can be found usually in most manufacturing that has a major and minor product. A company always pays more attention to major item than minor products. As the result, a lot of waste occurs along the production line of minor products, as is the case in the KYE exhaust fan problem.

4.2 Current State Result analysis

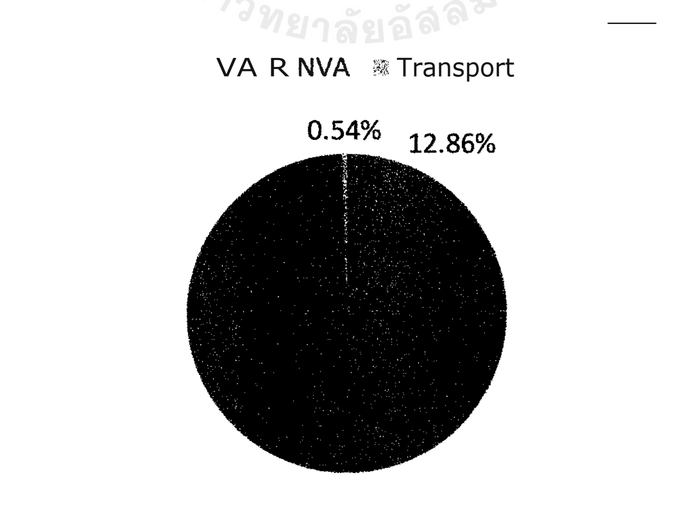
After we finished the simulation result, we planned to solve production problems within three criteria due to objective values:

1. Long production lead time
2. High work in process
3. Unbalanced production line

4.2.1 Long production lead time

Production has more non value-added time than value-added time for producing a finished motor. A lot of waiting time is caused from WIP that has to wait to be used in the next process. Another problem is transportation time. But in this case we can see little loss from transportation compared to total non value-added time, as in this graph.

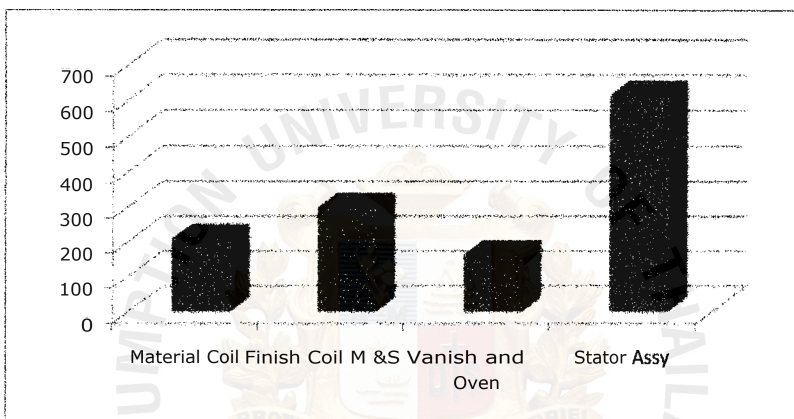
Figure 4.2: Percentage of VA, NVA and Transport time



4.2.2 High work in process

We can compare the ratio of amount of WIP in every work station. We realize that there is a high number of WIP in the finished stator assembly which means that upstream workstations have high production capacity. Hence, they produce faster than in the downstream process. Finally, there is a lot of WIP in before group G 16 C.

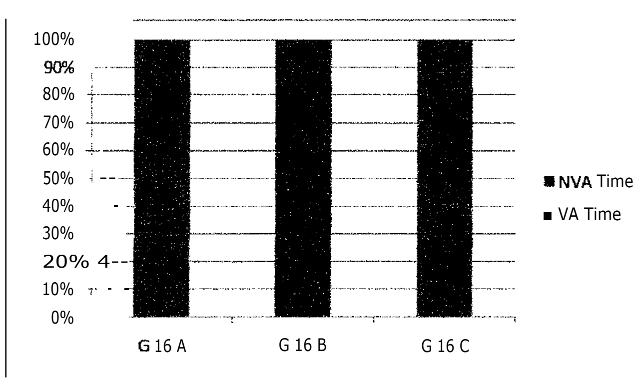
Figure 4.3: Work-in-process graph



4.2.3 Unbalanced production line

From the bar chart below, we can see unbalancing cycle time among workstations, which means that the efficiency of the production line would be low. This problem should be handled by cellular manufacturing. And it can also improve the result of all problems.

Figure 4.4: Cycle time at each work station: graph



4.3 Process reengineering Plan

After we analyze the results, we realized that cellular manufacturing can solve the problem of an unbalanced production line, which is the first clue to a production problem nowadays. But it cannot be handled easily, because we are going to change the workstation from fixed cycle time as a conveyor line to be a work group cell done by hand only. The result is that the distribution of cycle time data happened in every work station. So, it would be better if we solve this with a simulation program.

Process reengineering for cellular and batch size

Table 4.4: Process reengineering for cellular and batch size

Process Reengineering	Group 16 A		Group 16 B		Group 16 C		Production Batch Size		
	Details	Labor	Details	Labor	Details	Labor	G 16 A	G 16 B	G 16 C
Current state	Winding	2	Conveyor	9	Cell	2	900	450	450
Scenario # 1	Winding	2	Cell	4	Cell	2	900	450	450
Scenario # 2	Winding	2	Cell	3	Cell	2	900	450	450
Scenario # 3	Winding	1	Cell	3	Cell	2	900	450	450
Scenario # 4	Cell	1	Cell	3	Cell	2	900	0	450
Scenario # 5	Cell	1	Cell	3	Cell	2	900	0	100
Scenario # 6	Cell	1	Cell	3	Cell	2	450	0	100

This step for improvement is that we use the best result of cellular production to improve production batch size at every workstation. However, there are some constraints that we should consider, for example, minimum batch size and stock area.

Next, we would like to compare the best scenario in conditions of change over wasting when production has to change to a new model. Then, compare the new improved result with the old conveyor production line.

Table 4.5: Process reengineering for changeover to a new model

Process Reengineering	Time to change new model / day		
Current state with change over time	2	3	4
Scenario # 6	2	3	4

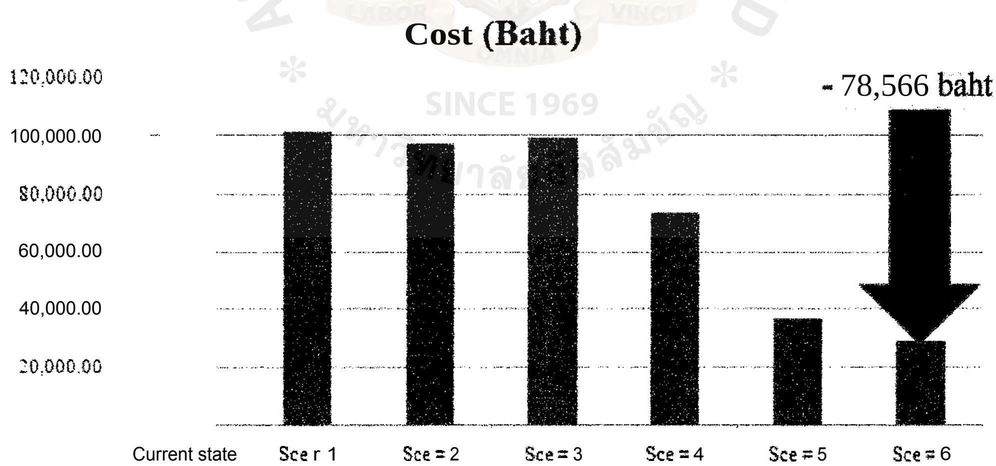
Then, we can change the simulation model to support our assumptions and compare the result for all scenarios in term of WIP, production lead time, and efficiency.

4.4 Reengineering simulation result and analysis

Table 4.6: Process reengineering simulation WIP result

Process Reengineering	WIP				Total (units)	Cost (Baht)
	Mat Coil	Finish Coil	Varnish	Stator Assy		
Current state	210	299	168	617	1,290	107,087.00
Scenario 1	218	387	168	503	1,276	101,409.00
Scenario 2	207	499	162	400	1,268	96,805.00
Scenario 3	492	414	164	383	1,453	99,183.00
Scenario 4	499	0	165	390	1,054	73,752.00
Scenario 5	501	0	163	38	702	36,660.00
Scenario 6	206	0	173	43	248	28,521.90

Figure 4.5: Cost saving chart



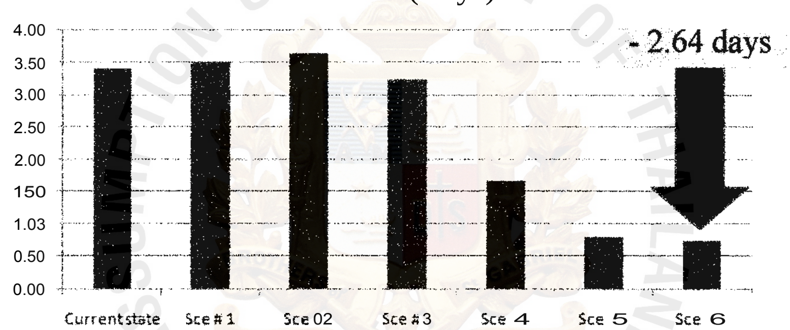
As in the WIP cost graph above, we can reduce the cost from 107,087 baht to 28,521 baht, which is 78,566 baht per model and equal to a 73.36 % reduction. In a Japanese company this amount of saving cost is good to compare with other kaizen quality improvements which can save only 2000 to 3,000 baht per year. Furthermore, they can extend this WIP saving method to other products also.

Table 4.7: Process reengineering lead time result

Process Reengineering	Lead time (Days)	Remark
Current state	3.41	
Scenario 1	3.49	16 B cellular 4 man
Scenario 2	3.65	16 B cellular 3 man
Scenario 3	3.24	Scenario 2 + Cell 16 A
Scenario 4	1.67	G 16 A& B in 1 Group
Scenario 5	0.80	Small Batch after Vanish = 100 set
Scenario 6	0.77	Small Batch before Coil = 450 set

Figure 4.6: Lead time improving chart

Lead time (Days)



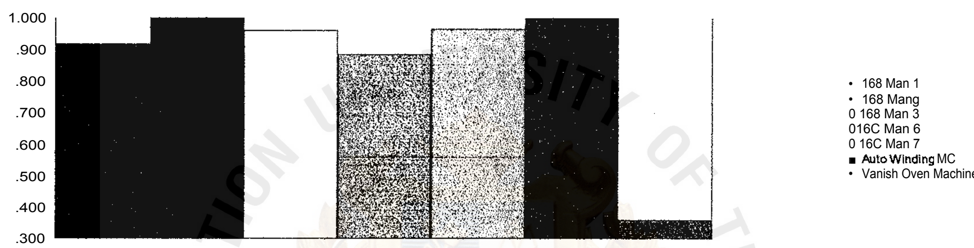
The production lead time can be reduced from 3.41 to 0.77, or a 78.00 % reduction compared with the current state, which means KYE can get finished good faster by 78% than previously. However, it is not only the waste of non-value added that they can reduce, as they can improve customer satisfaction to send their product to market.

Table 4.8: Accumulative change over time per month

Process Reengineering	Accumulative change over time (mins) Per month		
	2 Sku / day	3 Sku / day	4 Sku/ day
Current state + C/O	596.4	1,192.8	1,789.2
Scenario 6 + C/O	324.03	648.06	972.09

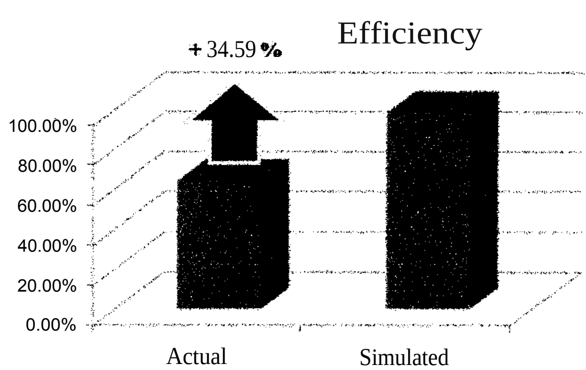
For change overtime waste, we can reduce change overtime from 596 minutes to 324.03 minutes per month because of the smaller cellular production line, compared with the long conveyor line. Mostly, KYE plan to produce a variety of products, as much as customers need with a lowest finished good inventory. But you can see the highest waste when they produce four SKUs per day with the conveyor line system": 1,789.2 minutes, which is equal to 3.72 working days. So, sometime they need to set up overtime for peak demands of customers. Moreover, we can see the better utilization of resource in the production line, higher than 90%, which means that we can avoid change over waste and waste for idle time

Figure 4.7: Resource utilization chart



For efficiency of the exhaust fan production line, we can increase this from 64.10% to 98.69 %, in Figure 4-8. It means that we can balance the cycle time at each work-stations by almost 100 %. Hence, the waste from waiting is deducted and also there is a positive effect for WIP among workstations.

Figure 4.8: Production efficiency improvement



Furthermore, cellular working can give more flexibility to KYE when demand changes. KYE can plan the workforce easier for both cut-off and add-ins, depending on the type of product. And in the future, change over time of cellular can be reduced by training. In the current state result, we need 13 staffs to set up the production line. But only 6 staffs are needed to work on cellular manufacturing, or a saving of 7 staffs, more than 55%

CHAPTER V

Conclusions and recommendations

From the problem statement in Chapter 1, KYE has problems in WIP, lead time, efficiency, effectiveness and also change over wastes. However, this cellular manufacturing improving project can save much money for the company and also improve efficiency and effectiveness. It is not only saving money, but also more flexibility when customer demand changes. The following is the total cost reduction breakdown.

Total cost reduction can be divided into three groups:

1. Cost reduction from work-in-process = **78,566 baht**
2. Cost reduction from shorter lead time
   = 2.64 days x 451 units/day x 107 = **127,398.48 baht**
3. Cost reduction from change over or setup time
   = 0.57 days x 451 units/day x 107 = **27,382.83 baht**

Totally, we can save **233,347.31 baht** for only one fan model.

In facts, KYE produce 11 models of electric fan. So, we can multiply the total average of WIP 13 million baht from the balance sheet by 73.36% of simulated reduction. This project would therefore save **9,500,000 baht** in total in the fan department.

Moreover, we can achieve improved efficiency of 98.69 % and effectiveness of 1,372 units / man / month. This means that this improvement project strengthens the production line.

However, we cannot avoid comparing our simulated result with the KPIs target, which was set up by the improvement team before starting this project, which can be shown in the Table below.

Table 5.1: Compare the simulation result with Project KPIs

KPI	Current	Target	Simulated	Pass
Overall Work-in-process (1000 baht)	100	50	28	OK
Production Lead Time (days)	3.41	1.00	0.77	OK
Production effectiveness (Units /man / month)	728.45	1,000	1,372	OK
Production efficiency (VA / LT %)	64.10 %	80 %	98.69 %	OK
Machine Change over (Idle minute / month)	596	400	324	OK

From the KPIs result, we realize that our improvements meet all targets with quite impressive results, especially for WIP which can save more than 70 %. It is not only cost saving from WIP, but also gives more potential and flexibility to the production line for competing in the market. It is necessary to produce what customers need and also in the shortest period of time. As a result of this project, we need only six hours to produce a finished product. Moreover, we can change to more models without set-up waste of a big production line as a conveyor to service greater variety of products to customers.

However, the amount of man-power which can be reduced from 13 to 6 men, illustrates that we can control staff easier. The point of working as a cellular manufacturer is to cut off types of waste as much as we can, and also balance the cycle time into the same level among all workstations. Thus, can reduce the staff problem by more than 50% in this project.

Finally, the ARENA simulation program can help us to improve production. Not only for normal production, but we also to learn about production failure. However, KYE now has other project improvements in terms of self maintenance at each workstation. It seems that workers need to love and care for their tools and machines. So, it would be better if we show them how much failure impacts on the production line, which is our concern for the next project of improvement as productivity consultants.

Recommendations and future study

Firstly, KYE should consider the production information and further implementation in the purchasing data. Because of our investigation, wrong purchasing can lead the company to waste raw material. The company should expand this cellular manufacturing project to the full production line including fan assembly and also for other models of fan. If the firm transforms to a fully cellular manufacturing method, they can save more than 9.5 millions baht, which is quite a lot in this economic crisis.

Secondly, KYE should train their staffs for cross functional work, because that can improve skill to perform more types of job. When we implement fully cellular manufacturing, it will need multi-skilled staff to group the workstation together.

Finally, this improvement concept should be used in other productions of Mitsubishi. We can envisage a lot of money in WIP reduction in the total company. And they would also have more tools to compete in this economic crisis.

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Appendix A

Simulation Model Validation

1. Troughput per day

No	Actual	Simulation
1	450	464
2	472	375
3	430	460
4	451	402
5	462	463
6	473	428
7	464	466
	459	455
9	460	462
10	451	471
11	452	461
12	454	466
13	455	466
14	458	411
15	469	465
16	470	338
17	465	466
18	463	393
19	464	472
20	462	388
21	453	467
22	461	395
23	463	464
24	462	461
25	460	468
26	459	425
27	458	461
28	453	431
29	457	465
30	463	460

Mann-Whitney Test and CI: C1, C2

```
    II Median
C1 30 460.00
   30 461.0n


Point estimate for ETA1-ETA2 is -0.00
95.2 Percent CI for ETA1-ETA2 is (-4.00,10.00)
W = 924.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.8941
The test is significant at 0.8940 (adjusted for ties)
```

2. Work-in-process from finished coil

No.	Actual	Simulation
1	298	346
	345	368
3	287	264
4	297	269
5	351	322
6	299	206
7		376
8	324	193
9	286	387
10	254	223
11	263	361
12	287	420
13	290	316
14	265	338
15	251	264
16	289	285
17	290	246
18	314	118
19	421	339
20	324	339
21	323	263
22	242	346
23	132	69
24	287	383
25	284	383
26	283	279
27	298	350
28	320	175
29	310	167
30	316	408

Mann-Whitney Test and CI: Actual, Simulate

```
          N  Median
Actual   30  293.50
Simulate 42  316.00


Point estimate for ETA1-ETA2 is -11.00
95.1 Percent CI for ETA1-ETA2 is (-47.98,34.98)
W = 1064.5
Test of ETA1 = ETA2 vs ETA1 net = ETA2 is significant at 0.7319
The test is significant at 0.7318 (adjusted for ties)
```

3. Work-in-process from varnish and oven

No.	Actual	Simulation
1	400	0
2	0	400
3	500	0
4	0	400
5	500	0
6	0	200
7	300	0
8	0	200
9	500	0
10	0	300
11	300	0
12	0	300
13	400	0
14	0	400
15	400	0
16	0	400
17	300	
18	0	300
19	500	0
20	0	300
21	200	0
22	0	400
23	400	0
24	0	200
25	400	0
26	0	200
27	400	0
28	0	300
29	400	0
30	0	400

Mann-Whitney Test and CI: Actual, Simulate

```
          N Median
Actual   30  100.0
Simulate 30  100.0


Point estimate for ETA1-ETA2 is 0.0
95.2 Percent CI far ETA1-ETA2 is (-0.1,100.1)
W = 968.0
Test of ETA1 = ETA2 vs ETA1 act = ETA2 is significant at 0.437
The test is significant at 0.4031 (adjusted for ties)
```

4. Work-in-process from stator assembly

No.	Actual	Simulation
I	681	671
2	663	661
3	564	538
4	762	735
5	589	487
6	721	781
7	494	491
8	756	783
9	642	487
10	439	380
11	421	400
12	491	496
13	431	400
14	421	507
15	467	400
16	489	475
17	435	400
18	562	437
19	452	400
20	462	433
21	469	400
22	489	542
23	495	515
24	421	308
[illegible]	435	577
26	472	468
27	427	478
28	421	400
29	482	477
30	360	400

Mann-Whitney Test and CI: C1, C2

```
    N Median
01 30 477.0
02 30 477.5


Point estimate for ETA1-ETA2 is 21.2
95.2 Percent CI for ETA1-ETA2 is (-33.0,67.0
W = 964.5
Test of ETA1 = ETA2 v  ETA1 not = ETA2 is significant at 0.4658
The test is significant at 0.4682 (adjusted for ties)
```