สำนักหอสมุดกลาง พระจอมเกล้าลาดกระบัง

A CASE STUDY OF APPLYING TQM AND TPS TO AN ELECTRONICS ASSEMBLY FACTORY IN THAILAND

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Research Title	A case study of applying TQM and TPS to an electronics assembly factory in Thailand
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ABSTRACT

This case study presents an approach in applying Total Quality Management (TQM) and Toyota Production System (TPS) concept to improve business performances for an electronics assembly factory in Thailand. The performances are evaluated with key performance index (KPI) in quality, operation performance and work in process of model A (A is one of finish goods that customer decided to use as a prototype in improvement project). The study is developed by firstly reviewing the secondary data from the customer evaluation scores and secondly collecting data from the actual work place. The customer evaluation scores results are also compared for rechecking to the company secondary data. The data collection period is limited between the year 2010 and 2011 to check the project performances before and after the improvement from applying the TQM and TPS concept. 2 tools of TQM, Ishikawa diagram and Pareto chart are applied as the problem analysis tools. While the application of TPS concept mainly comprises of setting up team organization (author is one of the team member), setting up team objectives in its KPI targets and time lines, then implementing the actions to achieve the KPI and summarizing the results. The improvement has been done in 3 departments of the assembly factory which are the production department, the quality assurance department and the business control department. The study result shows that applying TQM and TPS concept can improve the performances of the assembly factory following the setting KPI in 24.1 percent of non-conformance product reduction, 21.21 percent of operation performance increment and 21.38 percent of work in process reduction in which the main keys to succeed the improvement depends on the 4M factors in man, machine, method, and material.

Keywords: Electronics Assembly Factory, Key Performance Index, Total quality Management, Toyota Production System

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Chapter 1

Introduction

Nowadays the competitive situation for all business tends to increase strongly throughout either the local marketplace or international marketplace. To be survived in this situation, each organization has to be well managed its resources for its business in the continual improvement of quality, cost and delivery (QCD). Furthermore, to be survived is not satisfied its stakeholder but to be leader of the market with high rate of return in the investment is a must. It is not only the luck but a lot of effort as a professional one has to be taken place. As the market situation has changed from Supply market to be Demand market, customers have more power than the manufacturer. Profit equation has changed from Cost plus profit equal to selling price to be selling price deducted by cost equal to Profit. Profit equation for Supply market where the demand is more than supply is presented as equation 1.1, where as manufacturers have more powerful than customer then they can mark up the profit they want for selling the products. Profit equation for Demand market where the supply is more than demand is presented as equation 1.2, where as manufacturers have less powerful than customer then they have to control their cost to get the profit from the selling price. [1]

Cost + Profit = Selling price……………………………………………….equation 1.1

Selling price – Cost = Profit……………………………………………….equation 1.2

This study is concerned on the process improvement within an electronics assembly factory to create competitive advantage and get profit to the organization by applying basic concept of Total Quality Management (TQM) and TOYOTA Production System (TPS). As these 2 concepts are the decision of customer and top management of the case study company.

1.1 Company back ground:

The case study company is a Japanese factory located in Nakhonrachasima province, established in year 1995. Its regional office is in Bangkok and head office is in Japan. There are 5 business sections; first is an injection of automotive parts, second is an injection of electronics parts, third is printing and painting factory, forth is an assembly factory and the last is mold factory. Total man powers are about 2,000 people. See factory structure in the Figure 1.1

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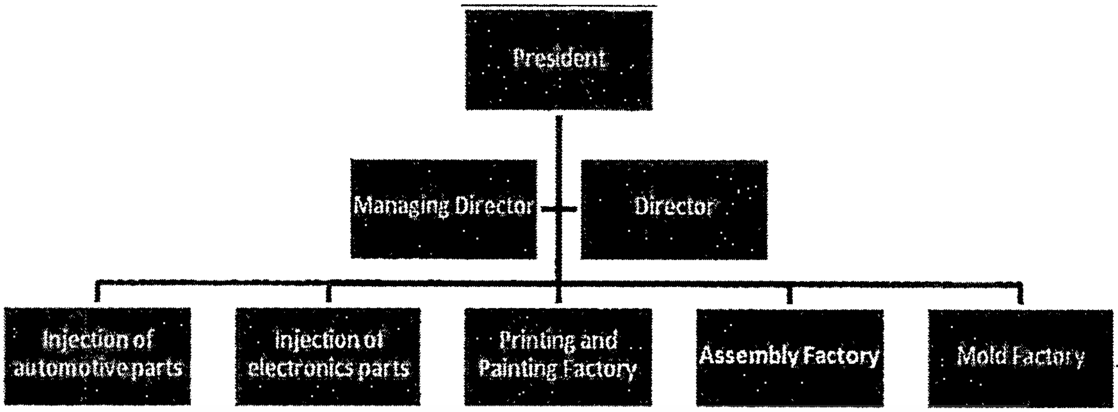

Figure 1.1: Factory Structure

This study is concerned on an assembly factory only. The assembly factory started its business in year 2006. Core business is assembly electronics components; main production process is relying on the workers. Total amount of assembly workers are about 800 people, with 2 working shifts, each shift is 8 working hours start from 8:00 am to 5:00 pm and 8:00 pm to 5:00 am. Overtime is from 5:30 pm to 8:00 pm and 5:30 am to 8:00 am. Working day is Monday to Saturday. Workers proportion is 70 percent of its own workers and 30 percent of subcontract workers. Assembly factory's organization is as presented in Figure 1.2, Assembly factory organization is consisted of top managements and 4 main departments which are Production department, Quality Assurance department, Production Engineering department, and Business Control department. Production department is responsible for assembly lines and machine maintenance, tools set up, and factory facilities. Quality assurance department is responsible for inspection, training and document controlling. Production engineering department is responsible for process improvement and tools designation. Business Control department is responsible for sales-delivery, material controlling- purchasing, and warehouse. There are 2 warehouses, one is its own warehouse which is located in assembly factory and other one is a rental distribution center (DC) warehouse located in Ayudhaya province nearby the customer factory. There are 2 sources of raw parts, one is direct purchasing from the nominate vendors and another one is supplied by customers. Customer supply is about 7.5% of all items by Kanban cycle 1:2:1, in 1 day the customer needs to supply raw parts directly to factory 2 rounds within 12 hours after receiving Kanban from assembly factory. The supply truck schedule is arrived factory at 7:30 am and 7:30 pm. The proportion of purchasing raw parts is about 92.5%, aside of 92.5%, 90% is

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from local and 10% is from oversea. Most of vendors are located in central Thailand around Bangkok as well. Normally all the parts are delivered to distribution center in Ayudhaya then the distribution center arranges the needed parts and some empty packages to factory twice a day at 10:30 am and 10:30 pm. Then these trucks return back to distribution center with goods from Nakhonrachasima factory. In some cases there will be direct shipment from vendors to factory if the vendors are failed in delivery schedule or quality issue.

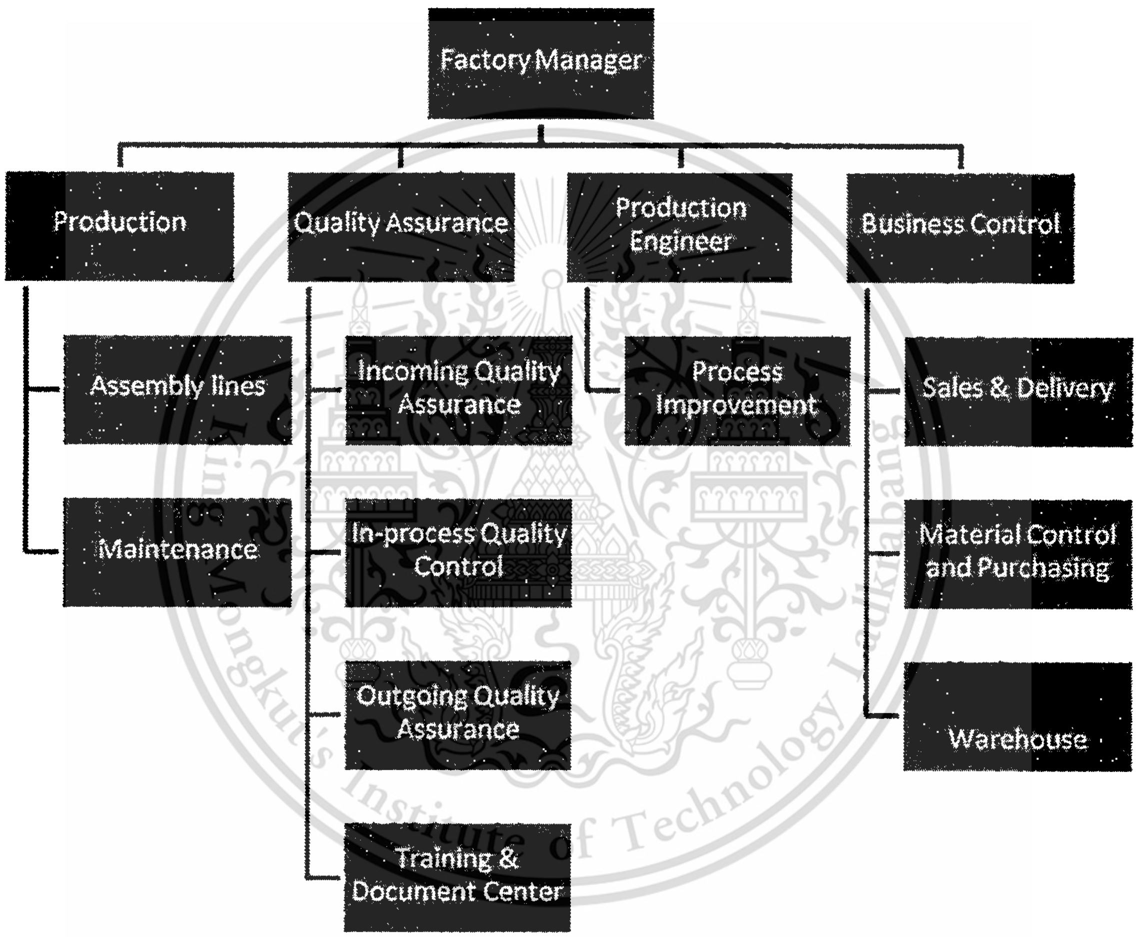

Figure 1.2: Assembly Factory organization

Its monopoly customer is located in Rojana Industrial Estate at Ayudhaya province then the customer is crucial for the company. Forecast information is given by customer to the factory and vendors together with the monthly and weekly assembly schedule. Customers' order is given monthly by electronic purchasing order in the website and customer production process is the pull system. Actual order is requested from customer by Kanban, Kanban cycle is 1:8:1 which is mean

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'in 1 day order, factory has to deliver goods to the customer 8 rounds every 3 hours after receiving the Kanbans from the customer'. This process is occurring between the customer and distribution center warehouse in Ayudhaya. While the factory ships the goods to distribution center twice a day, arrival time at distribution center is 3:00 am and 3:00 pm.

1.2 Statement of Problems

Customer evaluation score tends to decrease; non conformance is more than customer's target; this is cause less trust to the company. See table 1.1 for customer evaluation score that total score is decreased from 74.5 to 68 points especially in the quality of the product which is decreased from 20.5 points to 14 points.

Table 1.1 Customer Evaluation score in Quality, Cost and Delivery is down

		Result 2009 – 2010			
Evaluation topics	**Full score**	**3rd 09 Oct-Dec'09**	**4th 09 Jan-Mar'10**	**1st 10 Apr-Jun'10**	**2nd 10 Jul-Sep'10**
1.The Delivery of the product	42		35	35	
2.The quality of the product	36		20.5	14	
3.Documentation support	10		10	10	
4.Sales support & co-operation	12		9	9	
Total score	**100**		**74.5**	**68**	

Table 1.2 Customer Evaluation score criteria

Evaluation Result	**Point**	Grade	Score
1. Authorized is continued.	> 60	A	91 - 100
2. Authorized is continued conditionally.	40 – 59	B	76 - 90
3. Do not authorize.	< 40	C	60 - 75
		D	40 - 59

Table 1.2 presents customer evaluation score criteria; the company should get more than 60 points to continue the business with customer. Convert data of customer evaluation to be average unsatisfied score as presented by Pareto chart in Figure 1.3 below, firstly quality of the product is 55.6% unsatisfied, secondly is the sales support and co-operation is 26.7% unsatisfied, lastly the delivery of the product is 17.8% unsatisfied. Documentation support is nothing to be concerned as factory can get full score in this topic.

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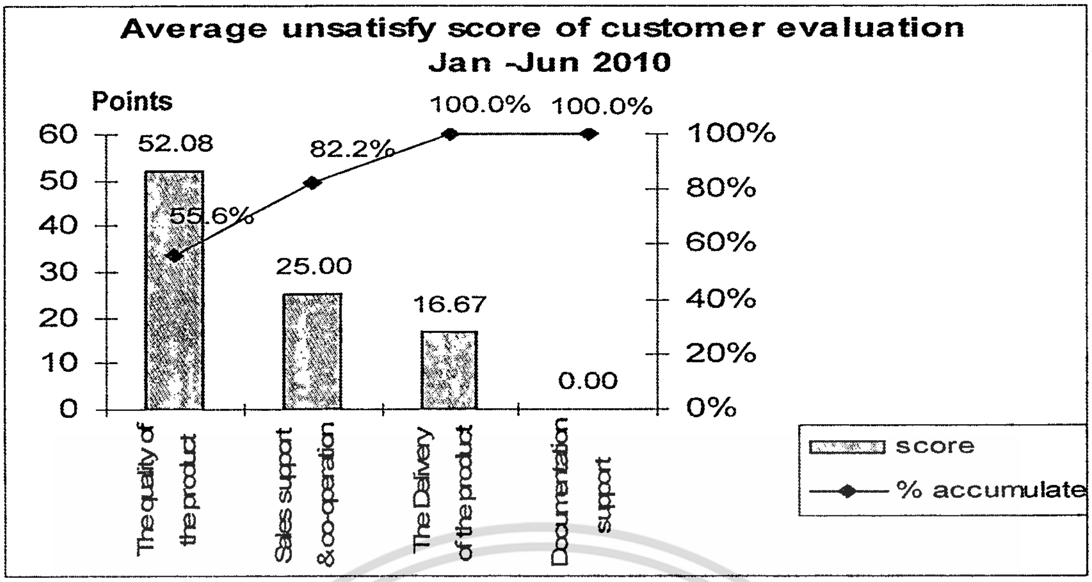

Figure 1.3 Average customer unsatisfied evaluation score Jan – June 2010

Quality of the product can be reviewed from customer evaluation score as presented in the table 1.3 below;

Table 1.3 Non conformance (NC) product record from customer January – June 2010

	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Total Delivery (piece)	879,019	1,171,085		
Total NC (piece)	1,630	2,774		
NG%	0.19%	0.24%		

Non conformance (NC) product quantity is 1,630 pieces (0.19%) in period January to March while total quantity of NC is increased to be 2,774 pieces (0.24%) in period April to June. This is affected to evaluation score as presented in Table1.1 down from 20.5 points to 14 points. Therefore the quality of the product is trend to decrease.

Sales support and co-operation detail is presented in table 1.4 as follow;

Table 1.4 Sales support and co-operation evaluation score January – June 2010

	Full score	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
4.Sales support & co-operation	**12**	**9**	**9**		
4.1 Speedy of response to customer inquiry	4	4	4		
4.2 Cost reduction co-operation	4	1	1		
4.3 The manner of contact person	4	4	4		

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From the sales support and co-operation score evaluated from customer, the cost reduction co-operation is the lowest score (1/4 points or 25%) while the score of other 2 topics is fully satisfy.

The delivery of the product is presented as in table 1.5, data is from customer record of total quantity shipped divided by lot size is equal to total kanban quantity.

Table 1.5 Delivery of the product record from customer in January – June 2010

Delivery Record 2010	**Result 2010**			
	Jan-Mar	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
Total ship quantity (Kanban)	24650	33474		
Total delay quantity (Kanban)	650	1		
Delay %	2.64%	0.003%		
On-time %	97.36%	99.997%		
Grade	B	B		

From delivery record in table 1.5, it is related to customer evaluation score in point 1 of table 1.1 that NK got 35 points from 42 points.

High quantity of WIP (Work In Process) which customer has converted data of parts supply in piece divided by daily plan to be outstanding day lead-time longer than standard. See figure 1.4 for the flow base manufacturing of stock parts supply from customer and table 1.6 for the actual stock of each processes that is different from customer target. Figure 1.4 presents flow base manufacturing of the parts supply from customer warehouse and deliver to assembly factory warehouse through put the assembly line, quality assurance process until finish in to Sub-unit kept in finished goods warehouse then ship to DC (distribution center) warehouse and deliver to customer finished goods warehouse. Total stock target from customer is 3.5 days but actual is 7.0 days. See stock quantity comparison between target and actual of each process as in table 1.6 below;

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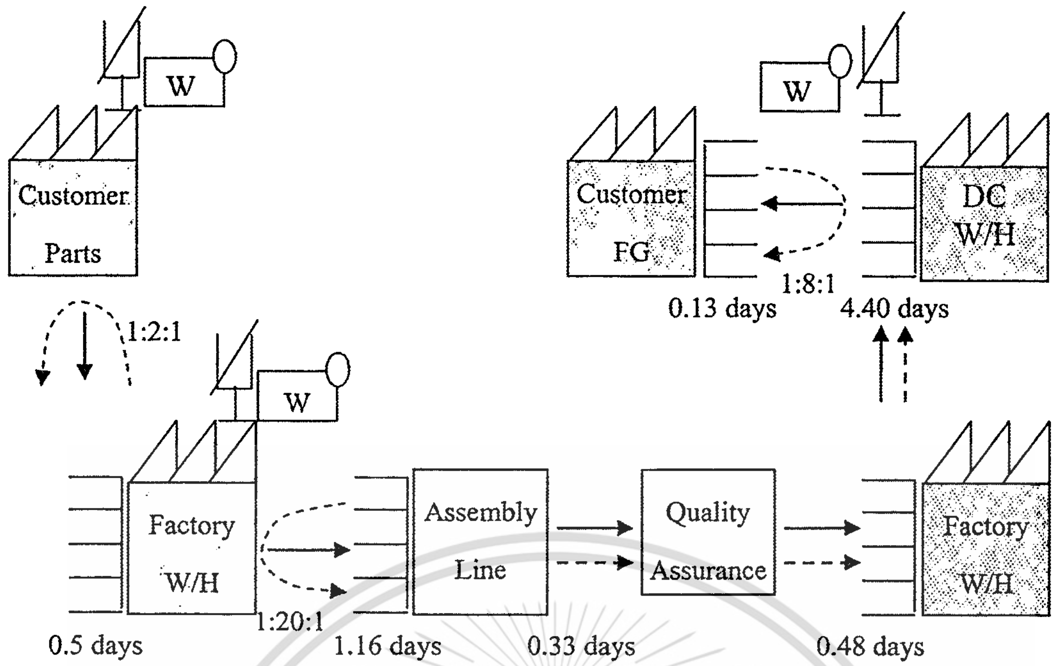

Figure 1.4Flow base manufacturing of stock parts supply

Table 1.6 comparisons of stock target and actual stock in day,

(From customer supply process until customer receives finish goods process).

Process	Target stock (Days)	Actual stock (Days)
Customer supply parts - Factory warehouse (Kanban cycle 1:2:1)	0.50	0.50
Factory warehouse - Assembly line (Kanban cycle 1:20:1)	1.00	1.16
Assembly line - Quality assurance	0.15	0.33
Quality assurance - FG warehouse	0.35	0.48
FG warehouse - DC warehouse	1.35	4.40
DC warehouse - customer FG warehouse (Kanban cycle 1:8:1)	0.15	0.13
Total	**3.50**	**7.00**

As a result the electronics assembly factory is force to do an improvement project in quality, cost control and production efficiency with customer to achieve customer satisfaction but maintain an organization profit at the same time. Project lead-time is 6 months from April 2010 to September 2010.

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1.3 Research Objective

1. Applying TQM (PDSA, Pareto and Ishikawa diagram) as a tool for analyze problem and applying TPS (5S, 7Muda, Standard work, Kanban, Kaizen, Just In time and Jidoka) as a tool for improves competitive advantage of the factory to achieve customer satisfactions.

2. Business performances are set up by the management as a representative of the company performances; which are consisting of 3 key performance indexes (KPI) as follow;

1) 50% of non-conformance products reduction.
2) 50% of productivity up by OPM (Operation Performance) increment.
3) 50% of Time and Space Saving by WIP (Work In Process) reduction to meet customer standard.

1.4 Scope of the research

1. Period study is year 2010 only as it is limited from customer project lead-time (April 2010 to September 2010).

2. Data in this study is focus on model A only as customer choose model A to be a prototype model of project improvement and Model A is expired in April 2011.

1.5 Research Procedure

The study is developed by firstly reviewing the secondary data from the customer evaluation scores and secondly collecting data from the actual work place. The customer evaluation scores results are also compared for rechecking to the company secondary data. 2 tools of TQM, Ishikawa diagram and Pareto chart are applied as the problem analysis tools. Then the application of TPS concept mainly comprises of setting up team organization, setting up team objectives in its KPI targets and time lines, then implementing the actions to achieve the KPI and summarizing the results of the project performances before and after the improvement from applying the TPS concept.

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Chapter 2

Literature review

The purpose of this section is to review the relevant literatures of the problem solving and TOYOTA Production Systems (TPS). Some related researches of the TPS concept are reviewed and presented in this chapter as well. As stated in the problem section in chapter 1 that there are 3 topics of customer satisfaction evaluation of the case study company that should be improved therefore TQM is reviewed as helping tools in problem analyzing and then Toyota Production System is the helping tools in problem solving. Conceptual of each following literature is;

2.1 Total Quality Management and Problem solving

Core competency of Total Quality Management (TQM) is Total Quality in people-focuses management system to meet or increase customer satisfaction with cost reduction to achieve competitive advantage of its business by continuing its improvement. Problem solving is one of the basic issues to be dealt with in management of every organization; problem can be defined as the discrepancy between what is expected and what is the actual out come. Problem solving in total quality management is not only moving out the unexpected situation but also is the way of continual improvement in the workplace and its products or services. There are several models in the problem solving such as The Plan-Do-Study-Act (PDSA) cycle of Doctor W. Edwards Deming, The Perry Johnson Method. This research focuses on the Perry Johnson methods as a main concept in problem solving tools to find out the root cause of problem then the several techniques would bring into the consideration as there is not only one correct way to deal with each kinds of problem according to the differentiation of the environment and the variable factors changing. Three main characteristics of the Perry Johnson Method are;

- It promotes teamwork in problem solving
- It leads to continual improvement rather than just "putting out fires"
- It approaches problems as normal by-products of change

Problem solving step is as follow;

1. Establish a problem solving team: no one can work alone in an organization; all the processes are related to each other. Each team member has his own experience, abilities and idea.

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2. Brainstorm the problem list: systematically thinking of problem, list out, identify and prioritize the problem that can be occurred.
3. Narrow the problem list down to the entries that are really problems based on three criteria which are compared standard, actual performance, and facts variance.
4. Create problem definitions clearly both description of the circumstance and description of the variance.
5. Prioritize and select problem to be managed by sequence. Perry Johnson recommends using the problem priority matrix which is created by ranking the problem in term of benefit to the organization and how much effort will be. The lowest extend number is the problem that should be resolved first.
6. Gather information about the problem; collect all available information that is related to the problem before find out the solutions. Information can be collect in 2 types; one is objective information and other is subjective information. [2]

2.1.1. Cause-and-effect diagram

This is one of quality control technique, was developed by Doctor Kaoru Ishikawa. Sometimes the diagram is called an Ishikawa diagram. It is also often called a fishbone diagram according to the diagram shape. Benefits of using this diagram are;

- Creating diagram itself is clearly instructive process.
- Reducing irrelevant discussion by grouping the problem
- Separate causes from symptoms and force to data collection
- Can be used with any problem.

This tool is not based on statistics, the chart is basically present as figure 2.1, and the main spine is pointed to the effect while the ribs are assigned to the causes that are considered to be the major factors. [2]

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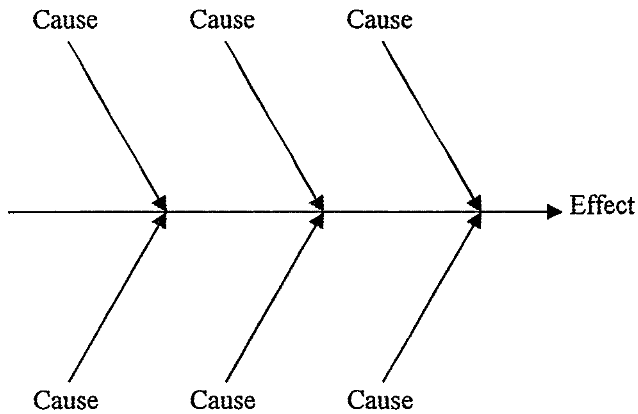

Figure 2.1 Basic Cause-and Effect or Fishbone diagram or Ishikawa diagram

2.1.2. The Pareto Chart

This tool is useful for separate the important from the minor. The chart was named by Doctor Joseph Juran, is named after Italian economist/sociologist 'Vilfredo Pareto' (1848-1923). The Pareto principle is that a minority of causes lead to the majority of problem. A Pareto diagram is a graph that ranks data classifications in descending order from left to right, as shown in figure 2.2. This diagram is used to identify the most important problems by visualizing. [2]

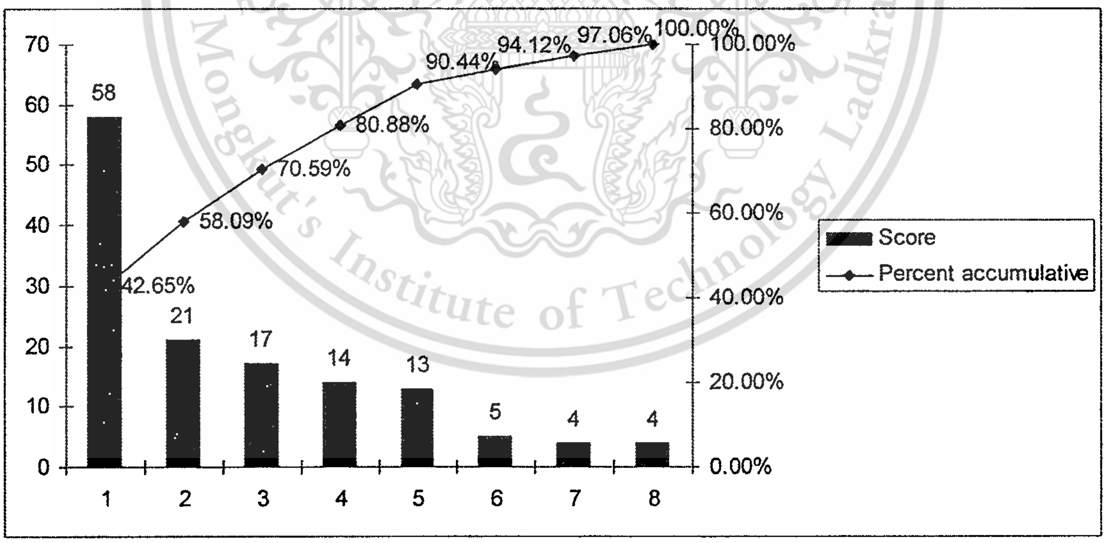

Figure 2.2: Pareto Chart or Pareto diagram

Basically the left axis is frequency of the occurrences while the right axis is cumulative of the total number of occurrences. The Pareto chart often present the most common of defects, the highest occurring type of defect, or the most frequency reasons for customer claim. Pareto

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chart was developed to illustrate the 80-20 rule, 80 percent of the problems cause from 20 percent of the various causes. [3]

2.2 TOYOTA Production System (TPS)

TOYOTA is the well-known brand name of Japanese automotive manufacturing company. TOYOTA GROUP is established by Mr.Sakichi Toyoda. At first it was weaving factory, but then change to be automotive factory. He has developed the JIDOUKA, one of the core concepts of TOYOTA Production System-TPS, in year 1896.

In year 1926 Mr.Kiichiro Toyoda, Mr.Sakichi's son, has developed J.I.T. or Just In Time other one of the core concepts of TPS.

In year 1956 Mr.Taiichi Ohno, engineering of Toyota Company, has developed Pull System and Kanban for apply in TPS. And Set up the basement of standardizes work in year 1978. [3] See structure of TOYOTA Production System House in figure 2.3 below.

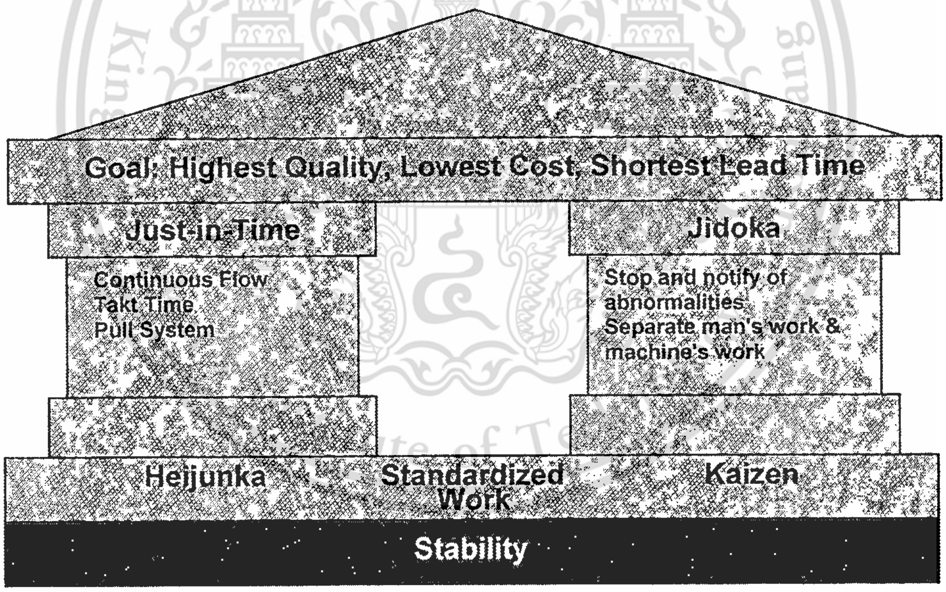

Figure 2.3: Toyota Production System House [4]

From Figure 2.3, TPS is consisted of

1. Stability or Basic production,
2. Standardized work
3. 2 pillars of Just In Time and Jidoka
4. Goals of TPS which are Highest Quality, Lowest cost and Shortest Lead-time.

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Toyota Production System has been generated from visiting a Supermarket in United State of America during site visiting at Ford motor in 1950. While the production system of Ford motor, famous car manufacturing at that time did not create an impression due to there was a large quantity of inventory exceed, process used was not very effective, inconsistency of the work during the day. But the way a supermarket reordered and restocks goods once the customer pick up it from shelf was very interesting. Toyota applied this concept to their inventory management by reducing the inventory level to the level that is needed in the small period of time then reorder later. This concept is now well known as Just-In-Time (JIT) inventory system. [5]

2.2.1 Stability or Basic Production

Stability or Basic Productions of TOYOTA Production System used in this study are 5Ss, 7Mudas and visual control.

5Ss are consisted of Seiri, Seiton, Seiso, Seiketsu and Shitsuke. "If you would like to achieve the target you should start from Seiri and Seiton of your work place first" as the complicated work place will close your eyes from the existing problems.

- Seiri (Sort): Separate the necessary things from the unnecessary things, review from the frequency usage of each thing within a day, a week, a month or a year. Get rid of the unnecessary things.
- Seiton (Set in order): Placement of the necessary things to be convenience for use, good visual control and safety for work. Everything is in its position with clearly identified.
- Seiso (Shining): Always cleaning and maintaining Seiri and Seiton to be in good condition. Keep work place tidy.
- Seiketsu (Standardizing): Good work environment, everyone acknowledgement of his or her responsibilities to the Seiri, Seiton and Seiso.
- Shitsuke (Sustain): Establishment of the good habit to maintain the 4S: Seiri, Seiton, Seiso and Seiketsu. Do not allow turning back to the existing condition before improvement and continue to improve it. [6]

Why 5S is an important basic production;

- 5S is not one man stand activity but should be participated from all members in the organization.
- If 5S activities are failed, it is difficult to be successful in other activities.
- 5S is efficiency indicator; good basic is bring to good efficiency.

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- 5S is changed corrective action to be preventive action.
- 5S is the helping tool for improving worker attention in the basic things.
- 5S is decreased the gap between each other.
- 5S is able to be done at work place or at home.
- 5S is one of the safety tools.

To achieve goal of the TPS and to ensure that process are capable as target result, Muri (overburden), Mura (inconsistency) and Muda (waste) have to be eliminated from the process. Elimination of the Mura (inconsistency) will balance and smooth the process, while elimination of the Muri (overburden) will improve its flexibility as the Muri (overburden) generate Muda (waste). Finally waste reduction or Muda elimination will decrease the cost down as waste is non-value added work but make the cost up. There are 7 types of Muda (waste) address in TPS [1];

1) Over Production
2) Unnecessary Stock
3) Unnecessary Processing
4) Transport
5) Defects
6) Unnecessary movement or motion
7) Waiting

Visual control is the communication tool for transferring the necessary information to be more clear understanding then everyone in the organization can take action in the expectation tendency. "Can be seen from far, can make judgment, able to use and convenience, easy to work on and fixable" are basic concept of good visual control.

Important and benefit of visual control;

1. Visual control can point out the emphasize spot which is lead to value added action to an organization as the human five senses can be ranged by perception percentage as follow:

75 percent of perceptions by seeing,

13 percent of perception by listening,

3 percent of perception by touching,

3 percent of perception by smelling,

3 percent of perception by taste,

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As a result, the good visual control is lead to the seeing which is the highest human perception percentage.

2. Visual control is the coaching tool not the evaluation tool. As visual control can lead to easily perception when the mistake exists, it could be seen more easily as well.

3. Visual control is creative tools as it is attract attention.

4. Visual control is a helping tool for problem solving and improving work quality.

2.2.2 Standardized work [7, 8]

There always be Muri, Mura and Muda in every work, there are 3 types of works classify by its valuable;

1) Value added work,

2) Non value added work but necessary and

3) Non-value added work and unnecessary (Muda) or waste.

Each process should be analyzed to review its possibility to increasing value. Therefore production process without Mudas should be more efficient. The setting up of standard production is necessary; Standard document, standard works and standard work place. The document that everyone can understand and follow to process the work in the assigned work place no matter whom they are. Standard documents concerned in standardized work are as follow;

1. Time observation sheet
2. Capacity sheet (one per cell)
3. Standard work sheet (one per cell)
4. Loading diagram (one per person)
5. Key point sheet (one per work station)

See appendices A for sample of the standard documents.

2.2.3 KAIZEN (Continuous improvement)

Definition of Kaizen is doing it better, doing it continuously and doing it stability. This is same as Total Quality Management concept but focus on quality of people (quality people will produce quality products). First step to do Kaizen (continuous improvement) is to have a kaizen mindset [9] which is;

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1) Everything can and should be improved.

2) Always think about an improvement even a second.

3) Don't complain but suggest.

4) Think of how to improve instead of why it can not be improved.

5) Think beyond common sense; try to find the better way even if existing is working.

6) Do not be afraid of problems.

Sequence or process to do Kaizen is totally 6 steps as follow;

1) Finding the problem or point to be improved

2) Present condition study

3) Analyze the root cause of problem

4) Idea / brainstorm for problem solving

5) Action follows the agreement idea suddenly

6) Follow up the result, set up standard and maintain.

After standard is set up, if there is any problem occur then process follow these 6 steps once again.

To do kaizen efficiency, we should do 3Gen which is

1) Genba – actual work place, this can let us make clear idea of the problem

2) Genbutsu – actual product, then we can review the problem point.

3) Genjitsu – actual situation, then we can acknowledge how the problem has occurred.

2.2.4 Just-In-Time (JIT)

By following Just-In-Time concept, it is not only help to minimizing stocks, shorten lead-time, smooth operation with no defective, long-term partnership with suppliers, reducing the batch size, continuous flow with reliability of machine, but also helps organizations to manage their operations more simplify, and finally reduce wastes [10].

2.2.4.1 Pull system

As present "Toyota production system house" in the figure 2.3 that Just In Time is consisted of Pull system, Takt Time and continuous flow. Previously most of manufacturing uses push system as a main production concept. Ordering information in push system would be distributed through the process then the first process would produce the product until finishing it

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and transfer (push) to the next process in the large quantity than it is needed, this causes of over inventory level. While Pull system concept is to produce the needed thing when it is needed and in the quantity needed only. This concept is related to the supply chain concept that is "produce the right things in the right quantity at the right time and transport to the right place with the right price to the right customer with the right information". In the other hand, order information in pull system will be sent to the last process only then the last process will pull the material or needed goods from the process ahead continuously.

In actual work, there is still some lead time between each process therefore materials will be delivered in smaller batch instead of continuous amount (one piece flow) then there is still some stock quantity in the pull system but smaller amount than push system, in other word, JIT minimizes stock instead of eliminating stock [10]. See Figure 2.4 and 2.5 for the comparison of push and pull system flow.

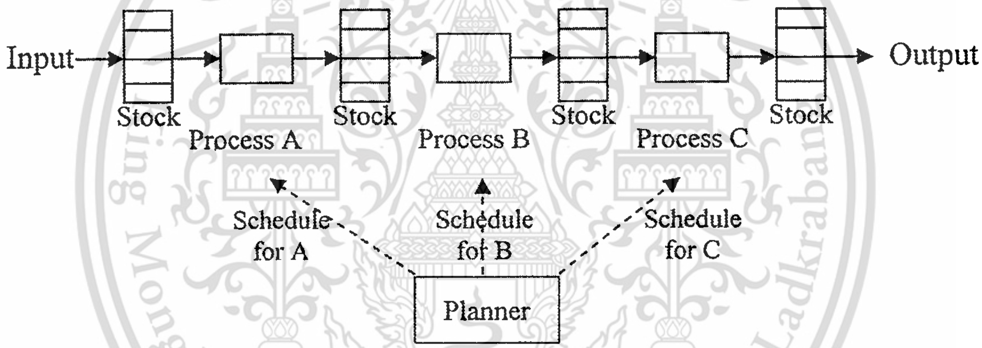

Figure 2.4 Push system, planner has to issue plan schedule to all processes A, B, and C

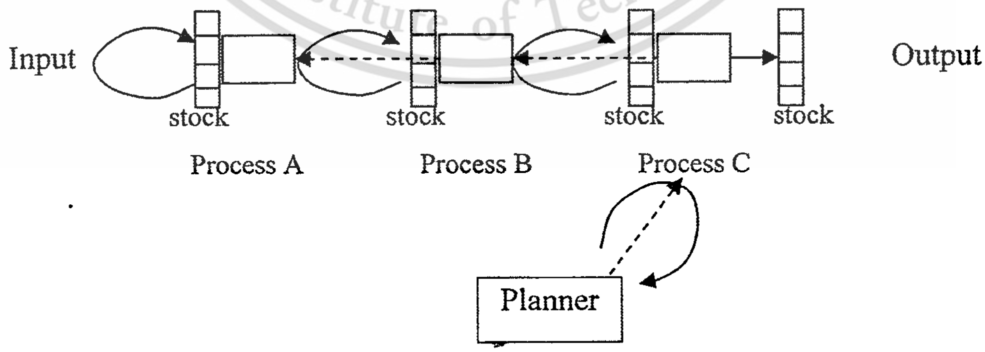

Figure 2.5 Pull system, planner only issue plan schedule to process C, then C will send request schedule to process B and B will send request schedule to process A respectively

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KANBAN (Index, Card)

The well known tool in pull system is Kanban. Kanban is an index or card; it is one of popular visual control tools used in Just In Time (JIT) concept. Objective of kanban is for replacing the slip, there are 3 types of slip: first one is parts slip, second one is order slip and the third one is delivery slip. Slip takes more time than Kanban, users would waste their time for writing the slip to the other process and the miscommunication would be occurred if users give the wrong writing. Kanban is suitable to use with the repetition process or cycle process. All process should follow kanban rule strictly, unless it will cause unevenly affect to other process.

Kanban Rules:

There are 6 regulations for using kanban which are;

1. All parts or goods must be 100 percent in a good condition. If there is any defective, it can cause unsmooth operation. Safety stock can be applied if the defective can not be solved.
2. Kanban must be attached on the parts all the time before use.
3. The next process must pull parts from the previous process as the same amount as the kanban quantity sent only.
4. The previous process must produce or fulfill the parts as the same amount as the kanban quantity received only.
5. Without kanban, must not produce and must not deliver the parts.
6. Lot size indicated on Kanban must as the same amount as the lot size of the parts or goods.

KANBAN CYCLE = A:B:C

A = Day of transportation i.e. Transportation will be in every **A** days.

B = Transportation frequency of **A** day i.e. There will be transportation **B** rounds in every **A** day.

C = Delivery lead time of **B** from Kanban sent until receive the parts or goods.

For example:

Kanban cycle 1:4:2 is mean in 1 day (A), transportation is 4 rounds (B), and delay or delivery lead time is 2 rounds (C).

If we send Kanban in the 1st round, the goods or parts will be delivered in the 3rd round.

If we send Kanban in the 2nd round, the goods or parts will be delivered in the 4th round.

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If we send Kanban in the 3rd round, the goods or parts will be delivered in the 5th round or 1st round of the next day.

If we send Kanban in the 4th round, the goods or parts will be delivered in the 6th round or 2nd round of the next day.

Kanban cycle 1:4:2 can be presented as in the Figure 2.6

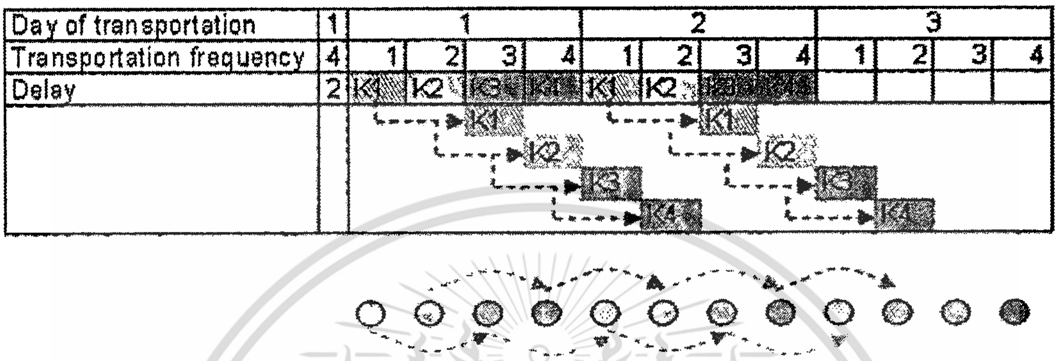

Figure 2.6:Kanban Cycle 1:4:2

One more example, Kanban cycle 2:1:1 is mean in 2 days (A), transportation is 1 round (B), and delay or delivery lead time is 1 round (C)

If we send Kanban in the 1st round of day 2nd, the goods or parts will be delivered in the 1st round of day 4th.

If we send Kanban in the 1st round of day 4th, the goods or parts will be delivered in the 1st round of day 6th.

Kanban cycle can be presented as in the Figure 2.7

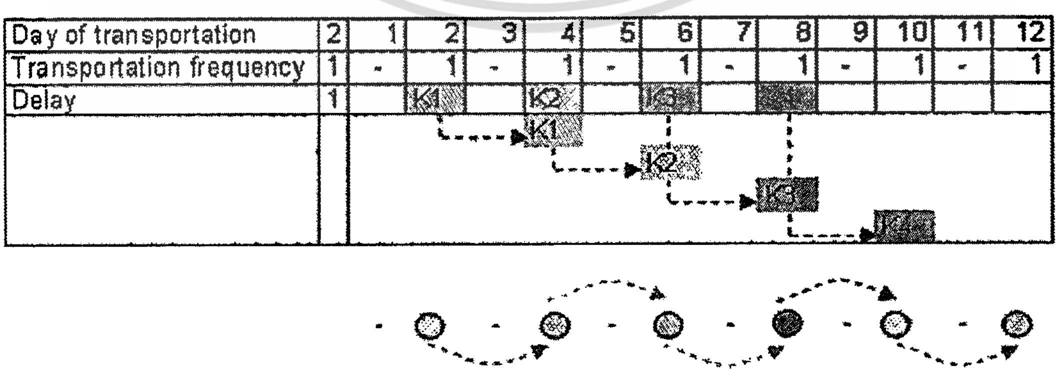

Figure 2.7:Kanban Cycle 2:1:1

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KANBAN Quantity

Kanban quantity is depended on the Daily usage, lot size of goods or parts and Kanban cycle. As presented in the figure 2.5 that Pull system is minimizing stocks than eliminating stock then there is a safety stock allow in setting number of kanban when an early implement of JIT system or there is any defective materials can not be solved. Safety stock can be decreased later on [10]. Number of kanban will be computed as presented in the equation 2.3,

$$\text{Kanban Qty (Piecs)} = \frac{Dailyvusage}{Lotsize} * \left(\frac{A*(1+C)}{B} + Safetystock \right) \text{..................} \textit{equation 2.1}$$

$$\text{Safety stock (days)} = \frac{DailyUsage}{Lotsize} \textit{*transportation Lead time.} \text{..........................} \textit{equation 2.2}$$

$$\text{Kanban Qty (Piece)} = \frac{DailyUsage}{Lotsize} * \left(\frac{A*(1+C)}{B} + leadtime \right) \text{......................} \textit{equation 2.3}$$

If any decimal number from calculation exists, the number of Kanban should be round up i.e. 7.1 round up to 8. Kanban quantity has to be separated in to C+1 portions i.e. if C = 2 then Kanban will be separated in to 3 portions. 1^{st} portion is at vendor or the process before, 2^{nd} portion is at Transportation process and 3^{rd} portion is at warehouse or the next process while the safety stock will be kept at the next process (warehouse).

For example; Kanban Cycle 1:4:2, Daily usage is 4,000 pieces; lot size is 200 pieces per pack from Kanban cycle 1:4:2 the lead time is 0.50 days

$$\text{Kanban Qty (pieces)} \quad = \frac{4000}{200} * \left(\frac{1*(1+2)}{4} + 0.50 \right)$$

= 20 * (0.75 + 0. 50)

= 15 + safety stock 10

= 25 pieces which will be separated in to 3 portions

10 pieces are safety stock at warehouse, 7 pieces are at vendor for parts preparation, and 8 pieces are on the way from vendor to factory.

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2.2.4.2 Continuous Flow

Traditional production (Lot production), each process will separately locate and has its own stock. Once operators finish their job, they will send the parts or push to the next process. Whereas the continuous flow process (pull system), the operators of each process will connect together and the last process will pull the parts from previous process. The concepts of setting up the process are simplicity and uncomplicated, continuous and more similar to the straight line as much as possible. Components are as follow;

1) 2S of 5S which is Seiri (Sort) and Seiton (Set in order).

2) One-piece-flow.

3) First-In-First-Out (FIFO).

4) Good visual control – indicate clearly of important information.

5) Present the flow of man, things (parts, WIP, Finished goods) and information visibly. See sample of flow base manufacturing in figure 2.8

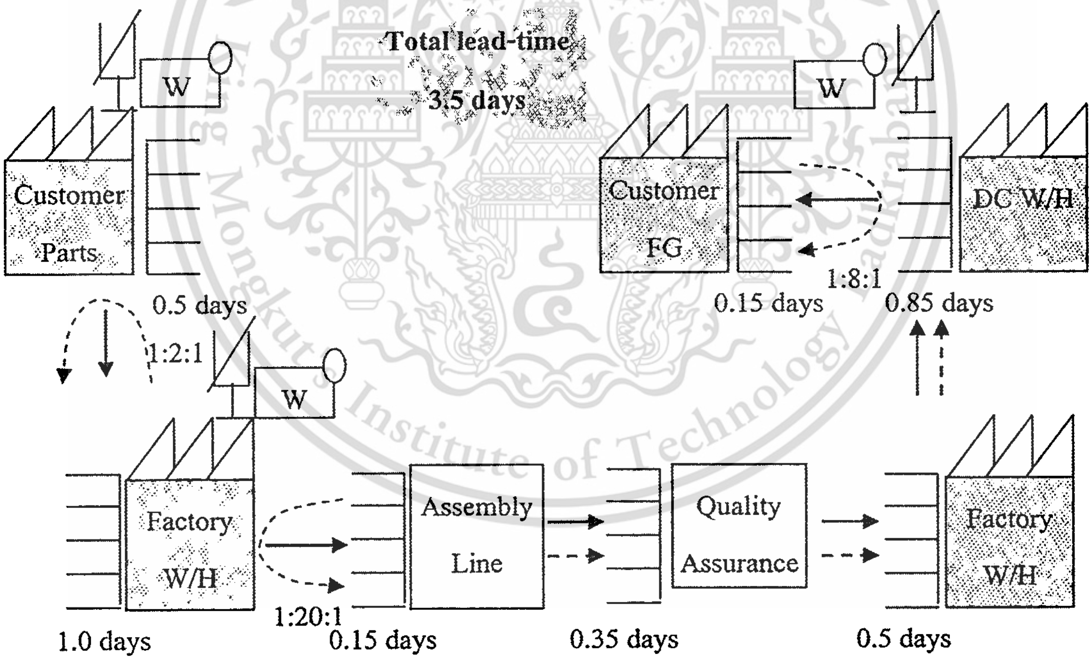

Figure 2.8 flow base manufacturing sample of stock parts supply

Procedures of the continuous flow;

1) Set the tools or machine follow working process

2) Tools adjustment should consider: motion movement, working area, easy to re-adjust.

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2.2.4.3 Takt time

Production efficiency is equal to output divided by input; input is man power while the output is quantity of product required by customer. Therefore if we would like to increase the production efficiency we either have to increase output or decrease input. Anyway in TPS system the output must be the same quantity as customer request then for this case we have to decrease input; by doing this **'Shoujinka'** is the key point.

Shoujinka is Japanese wording, its meaning is man power saving and man power reduction in the purpose of increasing production efficiency or increasing the operation performance.

Man power saving means production ability in maintain and improve its output while the production planning is changed or inconsistency, but efficiency is not decreased and can achieve customer requirement.

Man power reduction means increasing in production efficiency by reducing man power. The important things to be considered in Shoujinka are Operation Performance (OPM), Takt time, Actual takt time and cycle time.

Operation Performance (OPM) is the output compare with input of the process unit measure in percentage, OPM equation is presented in the equation 2.4

$$\%OPM = \frac{S\tan dardtime * output / day * 100}{workingtime * directmanpower} \quad \text{.................equation 2.4}$$

Standard time is given by customer from MOST (Maynard Operation Sequence Techniques) [11], DTS (Direct Time Study) method.

Output/day is the actual production output; target relies on the customer order.

Working time is the actual time of the direct workers that process product.

Manpower is the number of direct worker work for production process; worker who is not work for production line is not counted.

Takt time (T.T.) is German wording in describe a stroke in beating time, the time that is needed for manufacture one complete unit of product [8]. Can be calculated as the following equation;

$$\text{Takt Time} = \frac{\text{working time (excluded over time) per shift or per day}}{\text{Total daily Product requirement}} \quad \text{................equation 2.5}$$

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For example:

Working time 9 Hours/day, break time 1 Hour

Therefore total regular working time is 8 hours (480 minutes = 28,800 seconds)

Daily requirement 4000 pieces/day

Takt Time = $\frac{28800\,\text{sec}}{4000\,pcs}$ = 7.20 second/piece

Actual takt time or Direct takt time (DT.T) is the real working time that is included over time which line management agreed.

Actual takt time = $\frac{\text{working time (included over time) per shift or per day}}{\text{Total daily product requirement}}$ ....*equation 2.6*

For example:

Working time included over time12 Hours/day, break time 1.50 Hour

Therefore total working time is 10.5 hours (630 minutes = 37,800 seconds)

Daily requirement 5000 pieces/day

Actual Takt Time = $\frac{37800\,\text{sec}}{5000\,pcs}$ = 7.56 second/piece

Cycle time is the working time needed for each process since first process until the last process. The sum of cycle time from all processes together should be equal to takt time. If cycle time in any process is not equal to takt time, it can cause inconsistency of product output. For example if cycle time is more than takt time, the output would be less than target and may affect the stopping in production line. On the other hand, if cycle time is less than takt time, the out put would be more than target and may cause the excision in production and stocking.

2.2.5 Jidoka, (Quality Build In Process)

As presented Toyota house in Figure 2.3, Jidoka is one of the two pillars of Toyota house. The meaning of Jidoka is self control automatically or automation or autonomation. If unexpected thing occurs, machine will stop automatically and will not produce any defective outputs. Mr.Toyoda Sakichi has created this concept to the weaving machine by added the false detective program to the machine. The machine itself can stop once there is any abnormal of weaving thread. On the other hand, production process of an assembly line can be stopped once there is anyone in the line light up the andon signal then the line will stop and the person in

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charge would help to solve the problem. This is the same concept as automatic machine [12]. By doing defective protection, the non-value added work will be eliminated. If process is still running with the defective, it will waste time and resources for re-correct and make it right [13]. Steps to apply Jidoka are as follow;

1. Separate Man's work and Machine's work – we will know the root cause of the problem whether it come from Man or Machine.
2. In process quality control, stop and notify of abnormalities
3. Visual control – Andon or light alarm for machine, pacemaker for man, Kanban or production control board for parts.

3 basic rules of Jidoka are as following;

1. 100% produce only good product
2. Prevent defective of machines, tools
3. Stop trying to pick fault

One important thing in Jidoka is Jikoutei Kanketsu. Jikoutei Kanketsu is building up the quality mindset in process and its basic concepts are as follow;

1. Set up standard, condition of good product clearly: i.e. OS (operation standard), IS (Inspection standard), Patrol check sheet for control working to be in standard.

2. Do not produce defective product: using Poka-Yoke or failure detect tools to protect defective production.

3. Do not let the defective product leak to the next process: acknowledgment of abnormal, can judge the product whether it is good or defective, stop working when there is any abnormal thing, can review and trace back evidently.

2.3 Related Research Study

John S.W. Fargher Jr. (2000): presented several actual case studies result in implementation of Lean Manufacturing and Remanufacturing of Firms that Missouri Enterprises has been involved as a consultant. Missouri Enterprise is one of 73 National Institutes of Standard and Technology Manufacturing Extension Partnership (NIST MEP). The paper presented 7 steps to be successful in implementation of Lean Manufacturing, Orientation of Lean Manufacturing and Remanufacturing work shop simulation game, Descriptive of Value Stream Mapping and its advantage in waste elimination and 5 steps of mapping, Implementation of Subsequent Improvement Cycles, Subsequent improvement tools, Sample courses (5Ss, 6th S, Visual

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Management, Total Productive Maintenance-TPM, Quality improvement through statistical Process Control, Six Sigma, and Design of Experiments/Taguchi methods). The paper represented result of 3 case studies firms which are 1) USA Vacuum is able to create line balance with smooth and predictable production. Implement Kanban can help reduce model change over time. WIP is reduced; as a result USA Vacuum is able to meet their customer demand for vacuum cleaner. 2) Engine Plus Inc. is able to increase triple production capacity while maintain same number of man power, 25 percent of space saving and reducing production lead time from 8-9 days to be 1 ½ days and 3) Regen Technologies, Inc. is able to achieve 90 percent on time delivery to its customer within 8 hours, previously is only 60 percent achievement. Finished good inventory is decreased from $5 millions to be only $3 millions. [14]

Jeffery H. Dyer and Kentaro Nobeoka (2000): studied "knowledge-Sharing Networks" by interviewing 30 Toyota Purchasing managers in Japan and USA, 10 Senior Executives of Toyota's supplier in Japan and 11 Senior Executives of Toyota's supplier in USA. They also surveyed 97 suppliers of Toyota while received 48 suppliers back which is equal to 49.5%. The objectives of the study are to examine knowledge-sharing by Toyota and its 1st tier suppliers and to examine how to establish a new knowledge sharing network. The paper presented that 1) the network can be more effective than a firm in knowledge sharing as there were several knowledge within a network than a firm and Toyota can create 'coordinate principles' with its suppliers while suppliers learn more quickly after participated in Toyota's network. 2) 'Coordinate principles' in Toyota's network can created highly interconnected and strong tie network in knowledge sharing activities. 3) The research result is supported Rowley, Behrens and Krackhardt's (2000) assertion that interconnected and strong tie network is well suited for the spread out of existing knowledge than exploration for new knowledge. 4) The diversity of knowledge in the network can be decreased over the time, but Toyota has developed some elements to maintain the knowledge diversity. 5) Evolution of the network of Toyota's network suggests that it takes time to build up and maintain the relationship among the network to create the effective learning. Knowledge flows among the firm borders easily happen by creating the strong tie network with right partners. [15]

Rachna Shah and Peter T.Ward (2006): studied 'Defining and Developing measures of Lean Production' by clarify the meaning of lean production and its main component from existing

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literature. As Lean production is frequently used as a substitute of TOYOTA Production System (TPS). TPS was introduced in the U.S. in 1984 when Toyota and General Motors were setting up 'NUMMI' as a joint venture. They also identify measurement items by charting linkage between measurement instrumented and use rigorous, two-stage empirical method and data from large set of manufacturing firms, they narrow the lists of lean production to 48 items. Their objectives are firstly to resolve the semantic of lean production, secondly to propose conceptual definition of its multidimensional structure, and lastly to identify a set of 48 items to measure lean production and its components by using a rigorous empirical method. They did instrument development , sample domain and sample frame by considered the population of interested from all manufacturing firms (SIC 20-39) who have implemented lean production with 2 criteria; 1) firm must belong to SIC code and 2) firm has employees more than 100. They used Pilot study to identify a dimensional structure corresponding to lean production. They did data analysis by Corrected Item Total Correlation (CICT) > 0.40 and Comprehensive exploratory factor analysis, V.1 (CEFA). Then they did confirmatory analysis by CFA. The paper presented a conceptual definition of lean production by distill into 10 factors which are 1) supplier feedback (SUPPFEED), 2) JIT delivery by suppliers (SUPPJIT), 3) supplier development (SUPPDEVT), 4) customer involvement (CUSTINV), 5) pull (PULL), 6)continuous flow (FLOW), 7) setup time reduction (SETUP), 8) total productive/preventive maintenance (TPM), 9) statistical process control (SPC) and 10) employee involvement (EMPINV). All these 10 factors are positively and significantly related with each other ($p<0.001$), because *'lean production is integrated system composed of highly inter-related elements. The main objective of lean production is to eliminate waste by reducing or minimizing variability related to supply, processing time, and demand. Firms that are able to implement the complete set achieve distinctive performance outcomes that can result in sustainable competitive advantage.'* [16]

Mongkol Wanichpoonsuk (2009): studied Lean manufacturing and develop a plan for reducing the production cycle time of V-Ribbed belt manufacturer by using value stream mapping as a key tool. Batches production causes an inefficient in the manufacturer of V-ribbed belt. Then the value stream mapping is bring into account for studied the flow of the products and possibility improvement point in order to maintain competitive advantage and organization growth in South East Asia market. The paper presented that implementation of value stream mapping can help to identify and eliminate the wasting time in V-Ribbed Belt process, started from Belt building

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process until packing process thus production cycle time can be improved as the 7 wastes are eliminated from the process which are 1) Waste of over production, 2) Waste of waiting, 3) Waste of transportation, 4) Waste of inappropriate processing, 5) Waste of unnecessary inventory, 6) Waste of unnecessary movement, and 7) Waste of defect. Total cycle time is reduced 50.28 second or 18.6% and total throughput time is reduced 0.0206 days or 44%. [17] This study is concerned to V-Ribbed belt which is the automotive parts factory in Thailand then it is a chance for applying Toyota production system in the electronic assembly factory.

Alireza Anvari, Yusof Ismail and Seyed Mohammad Hossein Hojjati (2011): studied comparative study between Total quality management and lean manufacturing. By categorizes related literatures, analyze and review its methodology. The paper presents that there are 2 points different between LM and TQM. Lean is derived from Toyota production system, its main objective is wastes elimination, small input with greater output, whereas TQM is focus on customer satisfaction and control of business process by improving the productivity. While lean is focus on improvement of entire value stream and process mapping but TQM is focus on individual processes. The authors found that there are 3 main assumptions in the TQM concept which are 1. TQM can be classified in to 2 main portions; soft and hard. Soft TQM is focus on human resource management, leader ship, teamwork, training and employee participation. While hard TQM is focus on technical that can help in improvement production operation of value-added processes to create the customer satisfaction. 2. Both soft and hard TQM must be applied together to support each other. 3. Applying TQM core concepts (customer satisfaction, continuous improvement and teamwork) can lead to better organization performance. Anyway a chance of successful in TQM implementation is about one-fifth or one third as there should be strong motivation for participation of all members in the organization. Lean manufacturing is derives from Toyota Production System, key Lean concepts are quality build in process since first time, waste reduction by non-value added (seven types of Muda or wastes) elimination, continuous improvement, flexibility and long-term relation ships. Mian purpost is to shorter lead-time from production to customer. The key issues of Lean are 1) Value (values defined by end customer) 2) Value Stream analysis (set of actions to analyses the non-value added processes) 3) Flow (continuous flow through the supply chain) 4) Pull (action to achieve customer demand with less stock) and 5) Perfection (continuous improvement of the value, value stream analysis, Flow and Pull to eliminate the non-value added or wastes). Lean can not be applied if customer demand

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is unstable. Benefits of Lean implementation are operational improvement, administrative improvement and strategic improvement which can help in cost reduction and create the competitive advantage. Result from this study is presented some different between TQM and Lean as follow; 1) TQM and Lean purpose is same in wastes elimination but definition of waste is different. Waste in TQM is poor-quality-cost but waste in Lean is seven types of Muda. 2) TQM and Lean perspective is similar in seeing the organization as a system but TQM is focus on the internal organization but Lean is focus on the supply chain. 3) TQM is more focus in human while Lean is more focus on instrument techniques. 4) TQM and Lean are both focus on improvement, TQM is always use term "processes" while Lean is always use term "value stream" 5) The TQM literature is use statistical tool in many analysis while Lean is not much implicitly to this topic. 6) TQM and Lean are focus on continuous improvement but TQM is mainly on human improvement while Lean is mainly focus on standardization of work. 7) Customer satisfaction of TQM is customer's requirement both internal and external customer while Lean is focus on speed and efficiency to increase customer value (external customer). 8) Both TQM and Lean are giving more important to the supplier partnership. 9) Quality improvement in TQM is PDSA (Plan, Do, Study, Act) while quality improvement in Lean is focus on improvement activities. 10) In TQM measurements are done for identify problem and document improvement, while measurements in Lean are for planning and simulation. In conclusion Total quality management and Lean manufacturing are not clearly common and TQM can be a tool to support and create competitive advantage of Lean. [18] A comparison of two management philosophies is limitation. It is only theoretical study, it is a chance to apply in experimental.

Phan Chi Anh and Yoshiki Mutsui Ph.D. (2007): studied joint implementation of TQM and JIT practices upon competitive performance of manufacturing plants to find the mutual relationship between TQM and JIT. The Empirical study of TQM and JIT practices and their impacts on competitive performance in manufacturing factories (quality, cost, delivery and flexibility) is reviewed from14 papers. Applying of regression analysis to test the impact of TQM and JIT practices on competitive performance (quality, cost, delivery and flexibility) in 163 manufacturing plants from three industries: electrical & electronic (48 palnts), machinery (56 plants) and automobile (59 plants) in five countries; United States, Japan, Germany, Italia and Korea. Propose of 4 hypotheses which are H1: TQM significantly impact on competitive performance, H2: JIT significantly impact on competitive performance, H3: TQM and JIT will

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result in higher than TQM. H4: TQM and JIT will result in higher than JIT. Reliability of data, alpha value is 0.75 which is more than 0.6. Result of six empirical studies present that 5 cores of TQM are cleanliness and organization, customer involvement, process control, feedback and supplier quality involvement. Result of six empirical study of JIT presents that 5 cores of JIT are setup time reduction, JIT schedule, JIT layout, JIT delivery by suppliers, and pull system. And the two empirical studies presents that common of TQM and JIT can be considered for integrated implementation. TQM is significantly impact on conformance quality, unit cost of manufacturing, inventory turn over, on-time delivery, volume flexibility. JIT is significantly impact on conformance quality, unit cost of manufacturing, inventory turn over, on-time delivery, volume flexibility and cycle time. Implementation of TQM and JIT is result in significantly higher competitive performance (Quality, Manufacturing cost, Inventory Turnover, cycle time, on-time delivery and volume flexibility) level than implementation of only TQM or JIT. Limitation of the research is data collection as it is not large number of manufacturing plant, if expand survey population will help to find out more useful information appropriate conclusion. [19] There are more studies about the applying of Toyota Production system and Total Quality Management then thus it is a chance for practice with Japanese-Thailand factory.

Yuping Guo and Yachao Wang (2008): studied implementation of TPS production system and applying in numerous factories in China. Social and cultural of China is quite different from Japanese. Their main purpose is to analyze TPS's domestic operational status and promote its applicability research to the domestic enterprises by categorizes related literatures, analyze and review its methodology. The authors find that problems of implementation TPS in China are as follow; 1) National character: Japanese people have more sense of crisis situation than Chinese people. 2) Social culture of China create habit that is against TPS's implementation which are piece wage system that is create made to stock, culture of punishment that is cause from unreasonable business regulation, Chinese people lack of coherence and obligation in work, Chinese staffs lack of obey to their leader (more self confidence), Chinese people like to keep more stock if lack of stock they feel unsafe. 3) Many companies are learned or being learned TPS but not practice. 4) Many companies copy TPS as a method but do not apply its methodological concept with their work. 5) Most companies have weak management foundation. 6) Chinese factories pay more attention on instrument than improvement of efficiency. 7) Lack of flexibility as work must be separate clearly then each staff can not support each other. They propose their

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ideas confront against these problems as follow; 1) Implementation of continuous improvement practices. 2) Employee empowerment (employment mechanism and job training). 3) Promotion of coherence and obligation work. 4) Practice more than only learning or thinking. 5) Change to focus on operation at not cost instead of advance instruments, improve equipment and layout. 6) Green development and protect environment. The research limitation is less of literatures review as implementation of TPS in China is in an initial stage. [20] Different organization culture will create different threat of implementation.

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Chapter 3

Research methodology

This section describes the methodology adopted in the improvement of factory performance related to customer evaluation score of Quality, Cost and Delivery which are interpreted to the 3 Project targets: NCR ½, PPU ½, and TSS ½. Data information is retrieved from secondary data of company system and customer data report. Data collection is from work shop at the actual work place (Genba), actual situation (Genjitsu), and actual items (Genbutsu) follow concept 3Gens.

The methodology is addressed in the following seven topics then compares result on both customer evaluation score and company secondary data before and after project improvement of January 2010 until December 2010;

1. Review existing customer evaluation score (Report, secondary data from customer, secondary data of the company)
2. Setting up team organization for improvement (Author is one of team member).
3. Setting up objective and Target
4. Setting up time line schedule
5. Kaizen activities (work place and process improvement)
6. Summary Result and evaluation
7. Follow up and Action for continuous improvement

3.1 Review existing customer Evaluation score of company performance

Customer evaluates company performance by quarterly; 1^{st} quarter stands for April, May and June, 2^{nd} quarter stands for July, August and September, 3^{rd} quarter stands for October, November and December, 4^{th} quarter stands for January, February and March. Customer evaluation score is presented as in table 3.1 below; score of the 1^{st} quarter is 74.5 points and score of 2^{nd} quarter is 68 points.

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Table 3.1 Customer Evaluation score January – June 2010;

		Result 2010			
Evaluation topics	**Full score**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
1.The Delivery of the product	42	35	35		
2.The quality of the product	36	20.5	14		
3.Documentation support	10	10	10		
4.Sales support & co-operation	12	9	9		
Total score	**100**	**74.5**	**68**		
Grade		C	C		

Details of customer evaluation score in each point can be presented as following table 3.2, 3.3, 3.4, 3.5 and 3.6;

Table 3.2: Customer evaluation score details, January – June 2010

		Result 2010			
Evaluation topics	**Full score**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
1.The Delivery of the product	**42**	**35**	**35**		
1.1. Delivery 100% on time	28	21	21		
1.2. Delivery accuracy	10	10	10		
1.3. Packaging of the product is completed	4	4	4		
2.The quality of the product	**36**	**20.5**	**14**		
2.1 Defective rate in each month	26	13	6.5		
2.2 The reply of non-conforming level	10	7.5	7.5		
3.Documentation support	**10**	**10**	**10**		
3.1 correctness of Tax invoice or shipping document, including the unit price and description of parts	10	10	10		
4.Sales support & co-operation	**12**	**9**	**9**		
4.1 Speedy of response to customer inquiry	4	4	4		
4.2 Cost reduction co-operation	4	1	1		
4.3 The manner of contact person	4	4	4		

Table 3.3: Customer evaluation score details in Quality Topic, January – June 2010

Outsource Quality Assurance Evaluation			Result 2010			
Evaluation topics	**Criteria**	**Full score**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
1.In process claim result	If > 0.5% = 0 point	70	44	36.8		
2.Defective report delay	Delay 1 report = - 1 point	10	10	10		
3.Co-operation for take action	Main in charger	10	8	8		
4.E-mail feed back respond	Main in charger	5	4	3		
5. Visitors receive ordially	Main in charger	5	4	4		
Total score		**100**	**70**	**61.8**		

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Table 3.4 Data delivery of all models, January - June 2010

Delivery of all models Delay 2010	Result 2010			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Total ship qty	24650	33474		
Total delay qty	650	1		
Delay %	2.64%	0.003%		
On time %	97.36%	99.997%		
Grade	B	B		

Table 3.5 Data delivery of model A in January – June 2010

Delivery of model A Delay 2010	Result 2010			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Total ship qty (kanban)	7282	9211		
Total delay qty (kanban)	184	0		
Delay %	2.53%	0.00%		
On time %	97.47%	100.00%		
Grade	B	B		

Table 3.6 Grade criteria of the delivery performance

A	100%
B	90% - 99%
C	70% - 89%
D	69% - 0%

3.2 Setting up team improvement

The team improvement follows problem solving concept of Perry Johnson method which is described in point 2.1 of the Literature review. Team members are selected from different departments by TOP Management: one member, author, is from Business Control department, two members are from Production Engineering department; one member is from Production department; and the last two members are from Quality Assurance department, totally 6 main members. Customer also sets up two team members to participate in this project as Trainers for coaching the factory's team members on the improvement concept and theoretical of TPS. See the team organization of phase I (April – June 2010) in figure 3.1.

After finishing improvement activities in phase I, trainers suggest team member of assembly factory to select additional members to join the team for expand the knowledge and spread out the improvement activities in phase II. Two members from Business control

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department and two members from Production department were selected, totally new four members joined the improvement activities. Phase I team members of assembly factory transferred the knowledge that they has trained from trainers to Phase II members both theoretical and practical in the same way as what trainers transfer to them. Anyway organization of the team member in phase II is still the same as organization in phase I. See the team organization of phase 2 (July – September 2010) in figure 3.2 as well.

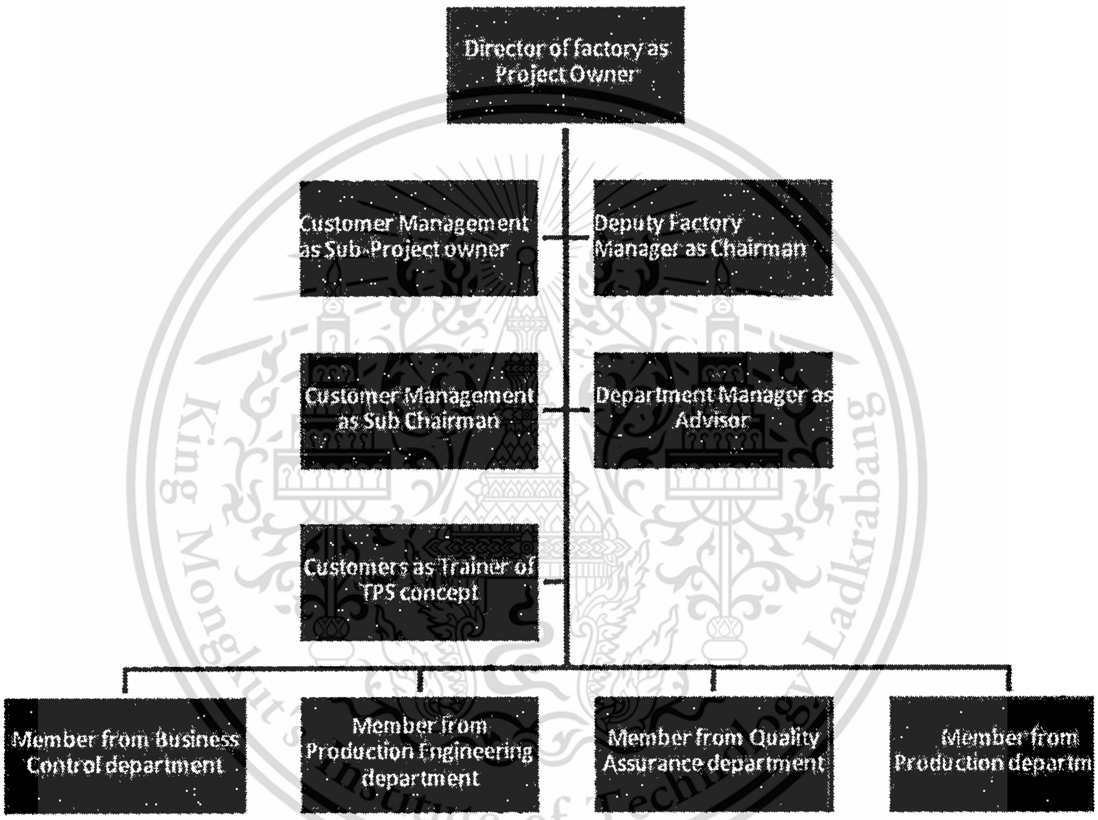

Figure 3.1: Team Organization of the improvement project phase I, II

3.3 Setting up Objective and Target of the project

Team choose the model line with its highest selling amount, on time delivery is failed and the highest percentage of defective claim back from customer as presented in Table 3.5 in previously page. Project Objective has been set up for the related topic to customer evaluation score which are;

1) Cost Reduction by Mudas eliminates and process improvement

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2) Build up production line that can satisfy customer requirement

And Project targets rely on the objective are;

1) 50 percent of Work-In-Process (WIP) reduction

2) 50 percent of Operation Performance (OPM) up from 40% to 60%

3) 50 percent of non-conformance (NC) products reduction

3.4 Setting up time line schedule

Improvement project lead-time has been fixed within 6 months, time line and project activities are list out as in table 3.7;

Table 3.7 Time schedule and activities of improvement project

Plan activities	Apr'10	May'10	Jun'10	Jul'10	Aug'10	Sep'10
1. Kick Off project	☆					
2. Present conditions study 2.1 Training team member (3 days/week) 2.2 Patrol work place (3 days/week)	Basic Production i.e. 5Ss, Muda, visual control	Standard work, Standard document, Standard work place, Kaizen	Innovation - JIT: Pull system, Kanban, Continuous Flow, Cycle Time, Takt Time, small lot, Butsuryuu - Jidouka: Man work, Machine work, quality in process, produce only good products, Poka-Yoke			
3. Analyze problem	←→					
4. Define Kaizen (Problem Solving method)		←→				
5. Set up Kaizen plan		←→				
6. Action in each area		←→				
7. Follow up result	weekly	Weekly	weekly	weekly	weekly	weekly
8. Summary result			1st			2nd
9. Report to all team members						

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9.1 Weekly Report 9.2 Final Report	2 times	4 times	4 times	4 times	4 times	2 times ☆

3.5 Kaizen or continuous improvement activities

Kaizen means continuous improvement and follows the concept of PDSA Plan-Do-Study-Adjust cycle of Doctor W. Edwards Deming.

Kaizen activities are focusing on 4M control and proceed in 3 major sections: Production section, Business control (Warehouse) section and Quality assurance section. Members from Production Engineering and Production department lead on Production assembly improvement, member from Business control department lead on the warehouse improvement, and member from Quality assurance department lead on quality assurance improvement. Each section area started by following activities in the table 3.5 as addressed in previously.

Trainers trained and coached team members during patrol the work place (on the job training: OJT). Data collection has been done in several ways: check sheet, Video, DTS (Direct Time Study by stop watch). After patrolling the work place for data collection then team member has the brain storming to find the solution or Kaizen way to solve the problem. And analyzing working conditions that is retrieved from secondary data of customer evaluation score by using cause and effect diagram as presented in the figure 3.2

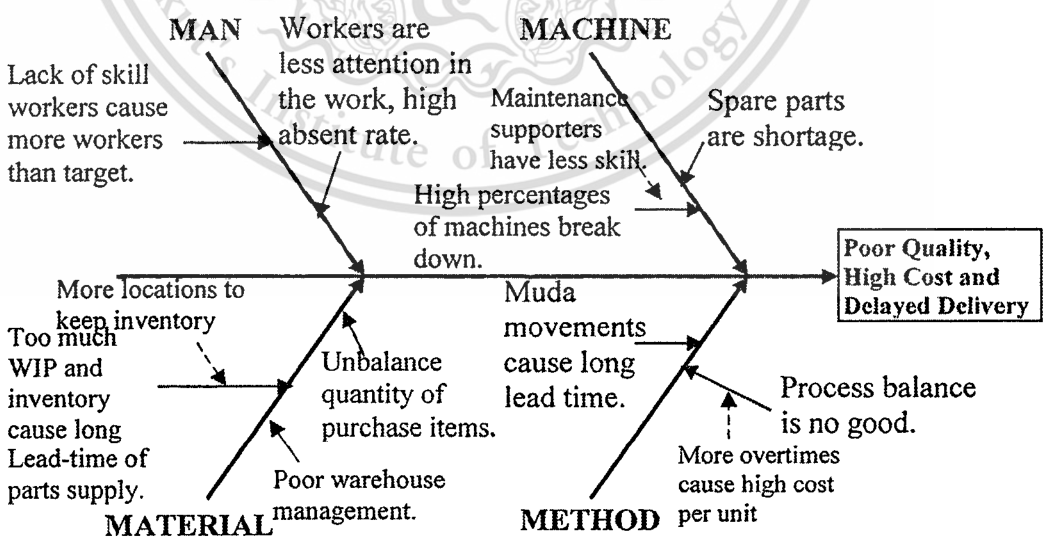

Figure 3.2 Analyze working conditions

To improve the working method and working place to be in the better conditions, the tools used in problem solving stage are Standard work, Standard Document and Standard Work

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place. Later on, the problem solving method has been announced to all related departments and start trial action by following the plan. A team member acted as a leader in the Kaizen activities of each area, worked with workers at that work place and recorded the data before and after kaizen activities then presented report of the Kaizen result weekly to team members and leader of all related departments. Once the result is acceptable then team improvement has to co-ordinate with each department for reviewing and setting up the new standard document of the improvement process then related department has to follow the revision standard. Kaizen step can be presented as Figure 3.3

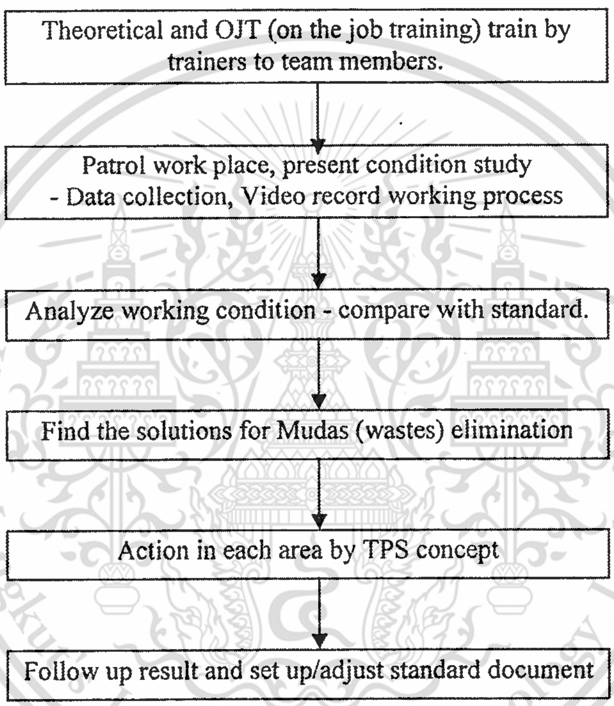

Figure 3.3:Kaizen step implementation

3.6 Summary result and evaluation

Summary result of project activities is presented quarterly in June 2010 and September 2010, the final report of project is also presented in September 2010. Presentation is done in power point file. Evaluation (Shokuba Shindan) is done by customer side (Trainers) and share information to both assembly factory members and customer management in junior and senior levels. Customer managements have visited NK, assembly factory, 3 times; firstly at kick off project, secondly in June 2010 and lastly in September 2010, they reviewed the project result report and on site visit (Genba).

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3.7 Follow up and Action for continuous improvement

After get the result by weekly, monthly, quarterly and until project finished, team members of assembly factory have to set up patrol schedule at work place then review and discuss with each department to maintain and/ or improve the improvement points and keep on going for expand the knowledge and kaizen activities to new members and other colleagues.

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Chapter 4

Results

Result of improvement activities practice by applying Toyota Production System to an electronics assembly factory and the result of key performance index (KPI) can be presented as following details.

4.1 Applying of Total Quality Management and Toyota production system

The objective of applying the Toyota production system is to improve competitive advantage of an factory in quality, cost and delivery performance of the model A which are presented as follow;

4.1.1 Production department result

Action results of production department on 4M: Man, Machine, Method and Material are as follow;

A) Man:

A1. Action on worker skills;

Co-operate with training center to train special skill to workers by following OS (operation standard), and L&R (Left and Right hand operation) both theoretical and practical.

- Line leader and Sub leader total 16 people / pass all equal to 100 %
- Worker soldering skill total 8 people / pass all equal to 100 %
- Worker cleaning skill total 16 people / pass all equal to 100 %
- Can set up spare worker for special skill total 7% / Team

A2. Action on man power absent rate;

Setting up person in charge to follow up workers when they absent, inform the fringe benefit and the absent cost to worker, motivational by party activities when workers can do achieve target output. Result after action on February 2011, manpower absent rate is reduced from 6.30 % in November 2010 to be only 3.02 % in April 2011 or 52 % in reduction. Data of manpower absent rate from November 2010 until April 2011 is presented in figure 4.1 on the next page.

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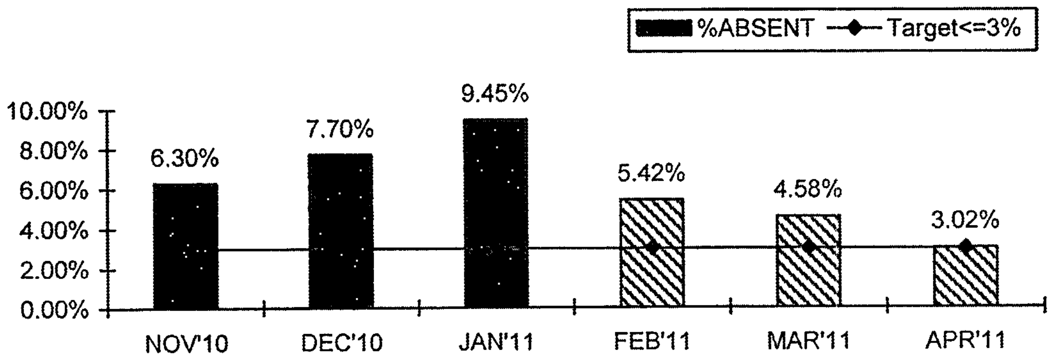

Figure 4.1 Man power absent rate

B) Machine: working on machine break down

Co-operate with maintenance section for data collection and action. Data on November 2010, total machine break down time which is caused production line stop is 23.78 hours, a side of machine break down time 17.45 hours is from lack of spare parts, 3.58 hours is from Dispenser machine and 2.75 hours is from Checker machine as present in figure 4.2 below;

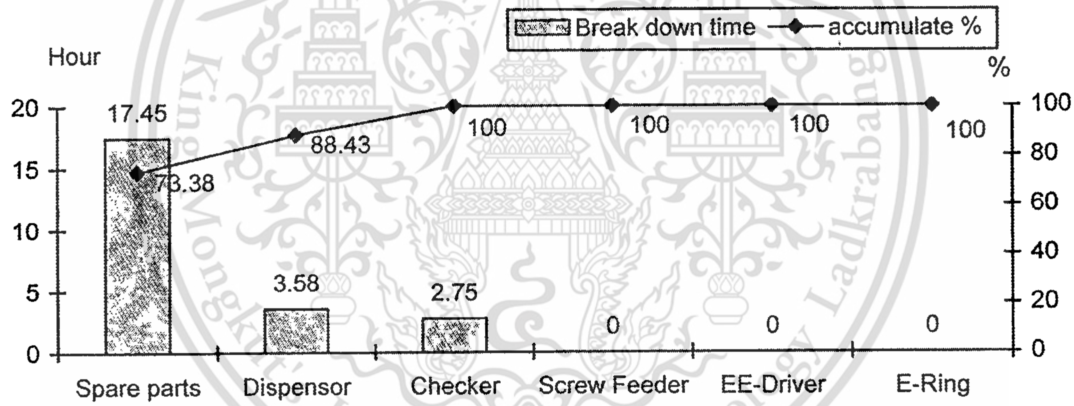

Figure 4.2 machine break down time of model A on November 2010

Action on spare parts by setting up safety stock of spare parts and check sheet to check spare parts quantity weekly. The results are controllable stock of spare parts and placing order to vendors on time. The machine breaking down causes of spare parts shortage is reduced from 17.45 hours to be 6.75 hours or 61.30% in reduction.

Dispenser machine: black tube is changed to be transparent tube, worker can see through the tube whether the red glue inside is nearly finish and they can call the maintenance guy to change the new glue for them before the glue dry and stuck in the tube. And the tip is changed from taping to be syringe, by doing this worker can inject the red glue to assembly parts more consistency than taping tip. The result of this action can reduce the Dispenser machine break down from 3.58 hours to be 0.33 hours or 90.70% in reduction.

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Checker machine: wire connector position is improperly cause of cut-circuit and machine break down 2.58 hours. Changing layout of wire connector can reduce machine break down to be 0.8 hours or 68.40% in reduction.

After action total machine break down time that is cause production line stop is reduced from 23.78 hours to be 7.88 hours or 67% in reduction on April 2011. See comparison graphs as in figure 4.3 below;

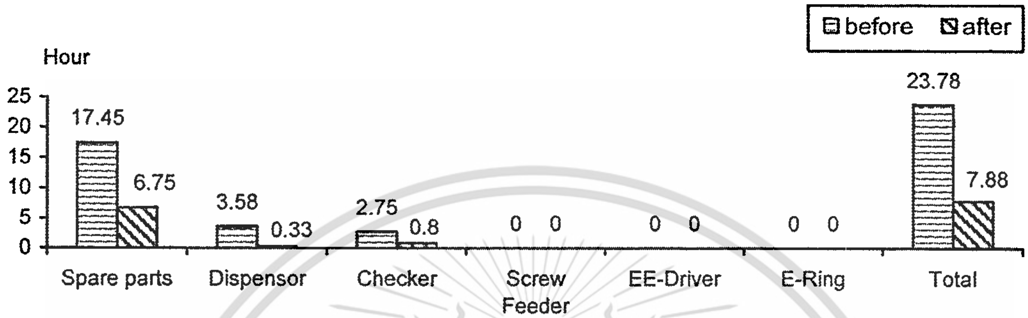

Figure 4.3 data of machine break down before and after action (Hours)

C) Method: result is based on practice model line which is focus on the Mudas (wastes) elimination, Line balance and processes sharing.

C1. Muda (wastes) elimination

- Muda of unnecessary movement of model A at station 1, 4, 7, 8, and 9 of sub-unit line is presented as in figure 4.4 regarding the takt time and cycle time of each process before action: cycle time of workers are more than takt time. Total lead time of the first piece is 347.56 second.

$$\text{Actual Takt Time} = \frac{\text{working time (included over time) per shift or per day}}{\text{Total daily Product requirement}} \quad \text{........equation 2.6}$$

Actual Takt Time of May 2010 = 21 Hours *3600 seconds / 2,664 pieces = 28.38 second/piece

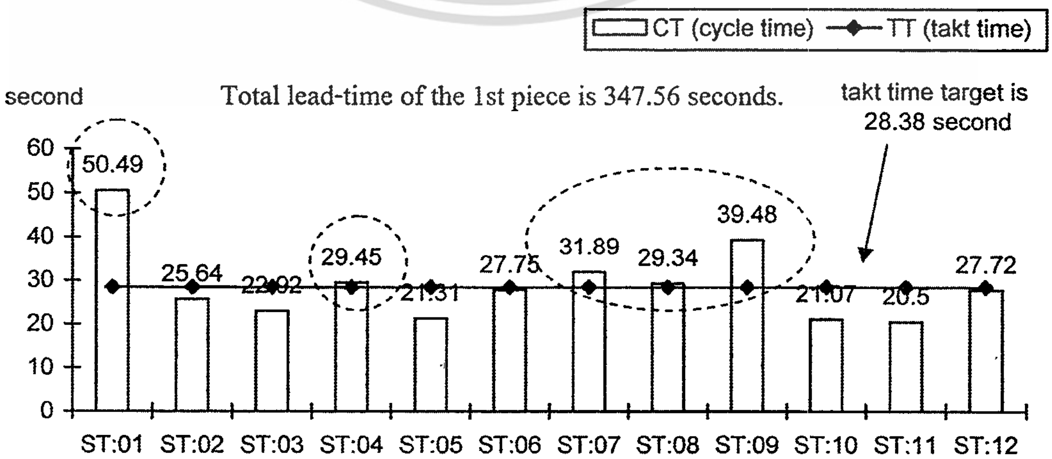

Figure 4.4 Cycle time and takt time of model A before action

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Station 1, Muda movement is from Left & Right hand operation and painting parts process is improperly. Cycle time of this station is 50.49 second which is higher than target takt time, action by re-layout parts position on working table and set-up the q-point for painting process. After the action, cycle time is reduced to be 27.98 second. Total time reduction is 22.51 second or 46.56%.

Before | Action | After

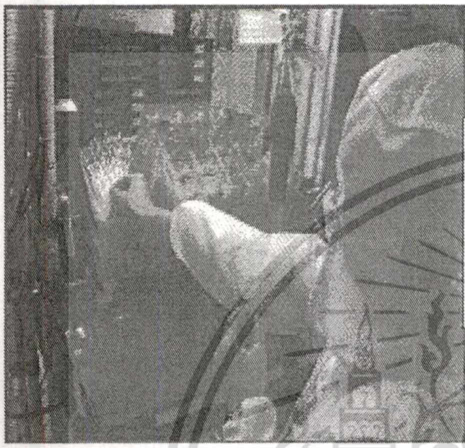

Figure 4.5a muda movement at station 1

Re-layout and set up the Q-point of painting.

Figure 4.5b layout at station 1 after improvement.

Station 4, Muda movement is from process operation, worker is loss time to set the parts in its position many times. Before the action take place, cycle time of this station is 29.45 second. Action by re-train operation process to follow its 2 steps, cycle time is reduced to be 24.15 seconds after improvement. Total time reduction is 5.30 seconds or 18%.

Before | Action | After

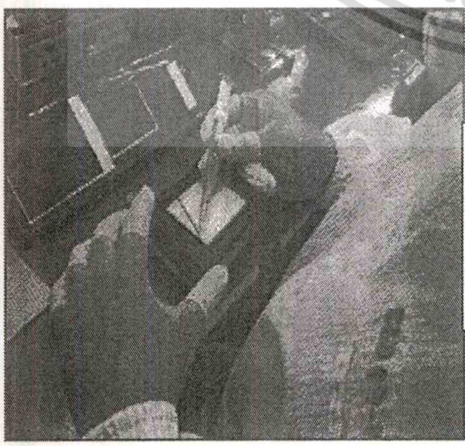

Figure 4.6a operation standard at station 4 is not appropriated.

Re-train operation process.

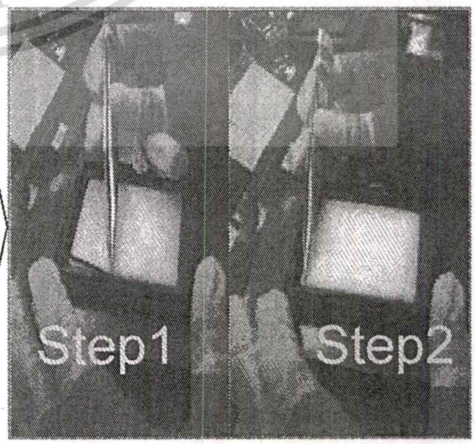

Figure 4.6b setting parts process at station 4.

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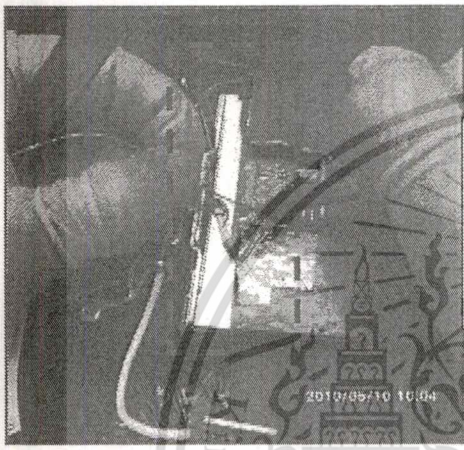
Station 7 and 8, Muda movement is from tools position improperly. Muda of work in process (WIP) is over limit quantity. Before the action take place, worker is re-soldering the wire many times as the cover jig is moving then worker loss her time to take the solder ball out from parts. Cycle time of these 2 stations is 31.89 and 29.34 seconds. Action by fixed the tool position (stable), cycle time is reduced to be 20.43 and 24.61 seconds after improvement. Total time reduction is 11.46 and 4.73 seconds respectively. Work in process (WIP) is reduced as well.

Before | Action | After



Repair the cover jig.

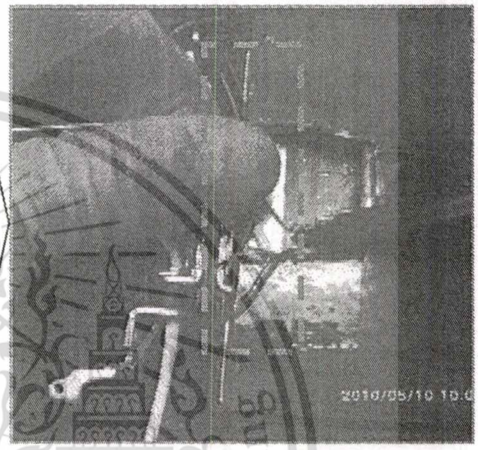
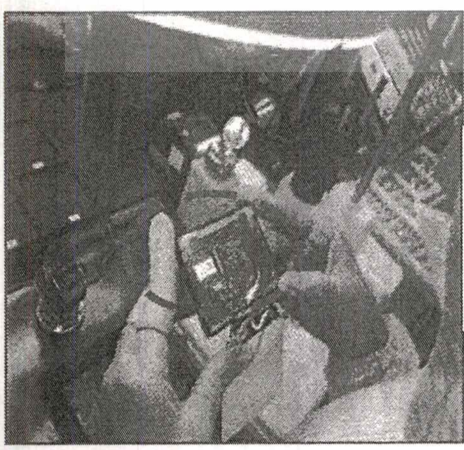


Figure 4.7a jig position at station 7 and 8 is moving.

Figure 4.7b fixing jig at station 7 and 8.

Station 9, Muda movement is from worker does not work follow operation standard (OS) processing then she loss her time in appearance checking process. Before the action take place, cycle time of this station is 39.48 seconds, after the action by re-train work instruction (WI) to worker and share some processes to station 7 and 8 the cycle time is reduced to be 25.94 seconds. Total time reduction is 13.54 seconds or 34.30%.

Before | Action | After



Re-training worker's skill.

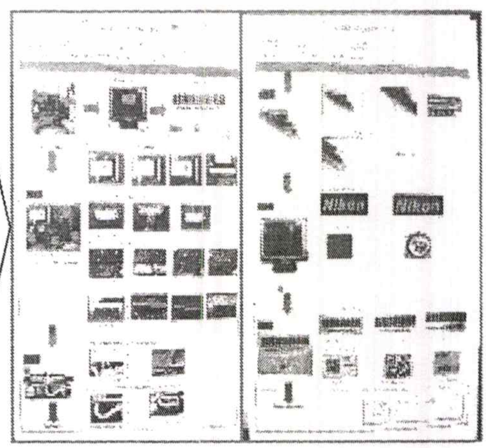


Figure 4.8a process appearance checking at station 9.

Figure 4.8b muda movement is eliminated by working follow WI.

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Cycle time of sub-unit line of model A at station 1, 4, 7, 8 and 9 before and after the action take place is summarized in the table 4.1 and figure 4.9;

Table 4.1 Cycle time of sub-unit of model A at station 1,4,7,8, and 9 before and after action

Cycle time (second)	Target Takt time (second)	Before action (second)	After action (second)	Reduce time (second)	Reduce time (%)
Station 1	28.38	50.49	27.98	22.51	44.58
Station 4	28.38	29.45	24.15	05.30	18.00
Station 7	28.38	31.89	20.43	11.46	35.94
Station 8	28.38	29.34	24.61	04.73	16.12
Station 9	28.38	39.48	25.94	13.54	34.30

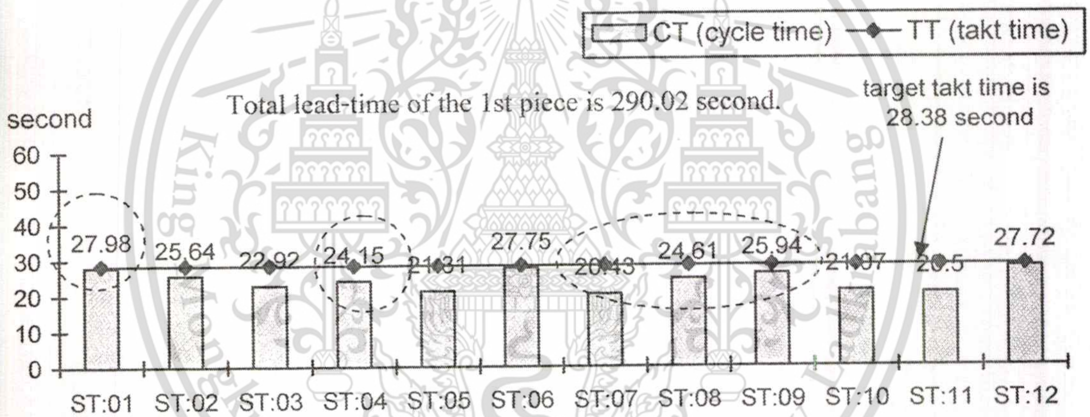

Figure 4.9 cycle time and takt time of model A after action

The cycle time of all stations in sub-unit line can be reduced and is lower than 28.38 second. Total lead time of the first piece is reduced to be 290.02 seconds. Muda of unnecessary movement of model A at station 1, 4, 7, 8, and 9 has been reduced on May 2010.

Kaizen team is also improvement main line on June 2010 by muda elimination too. Before action, total lead-time of the first piece of main line is 932.10 seconds. After action, total lead-time of the first piece of main line is reduced to be 863.64 seconds. See cycle time of each process at main line of model A before and after action in figure 4.10 and 4.14 respectively. From figure 4.10, cycle time of station 2, 3, 5, 6, 9 are higher than 27.20 second which is target takt time.

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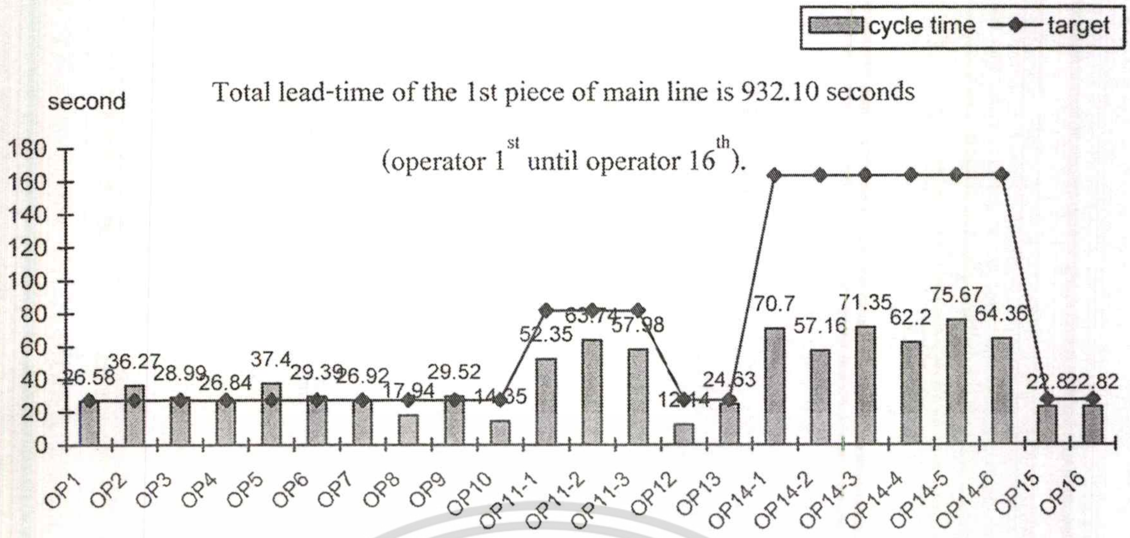

Figure 4.10 cycle time of main line before improvement on June 2010

Kaizen team has take video for analyze muda of main line and do process improvement of each station. Example of the muda elimination is as follow;

Station 2, Muda movement is from the layout of parts on work table is too high level cause worker loss time to reach the parts, cycle time is 36.27 seconds. Improvement by re-layout the parts position on working table to be lower level, convenience movement. Cycle time after improvement is 22.95 seconds; time is saved 13.32 seconds or 36.72% in reduction.

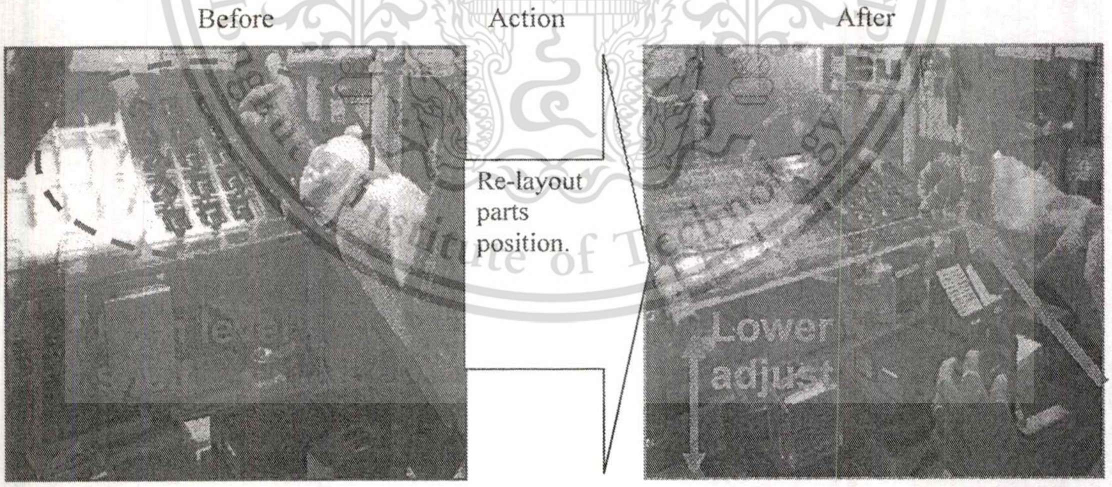

Figure 4.11a position of parts on work table is inappropriate.

Figure 4.11b position of parts on work table after improvement.

Station 5, muda movement is from parts direction that is not suitable with assembly process. Worker has to rotate parts before assembly, cycle time before improvement is 37.40 seconds. Improvement by rotate direction of the tool on work table 90 degree. Cycle time after improvement is 26.94 seconds; time is save about 10.46 seconds or 27.97% in reduction.

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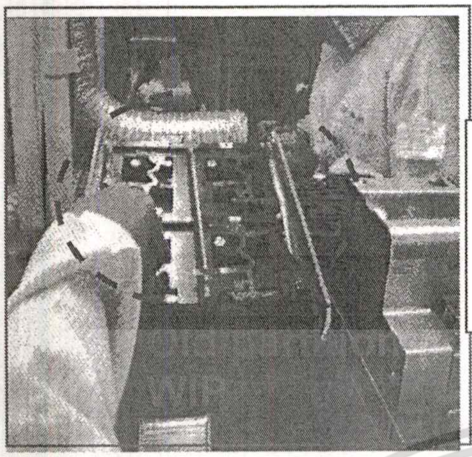
Before Action After



Rotate direction of the tool on work table.

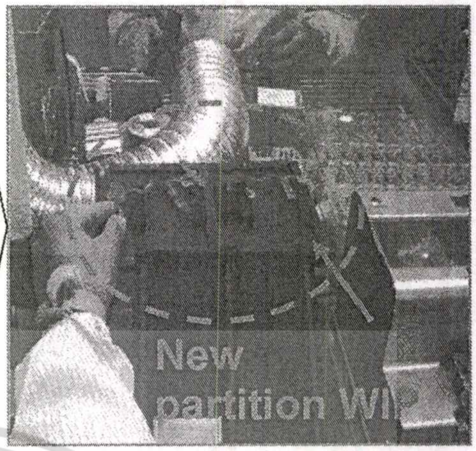


Figure 4.12a parts direction is inappropriate with assembly process.

Figure 4.12b parts direction on work table after improvement.

Station 9, muda movement is from layout of parts on working table. It is difficult to reach and cause worker loss time in movement during assembly process. Improvement by re-layout the parts position to be near worker hand. Cycle time before improvement is 29.52 seconds. Cycle time after improvement is 22.51 seconds. Time is saved 7.01 second or 23.75% in reduction.

Before Action After

Re-layout parts position.

Figure 4.13a position of parts on work table is inappropriate.

Figure 4.13b work table at station 9 after re-layout.

Summarize cycle time before and after muda elimination of main line of model A station 1 to station 9 is presented in the table 4.2 and figure 4.14 as below; time is saved after action and time of all improved station is lower than 27.20 seconds.

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Table 4.2 Cycle time of main line of model A at station 1 to station 9 before and after action

Cycle time (second)	Target Takt time (second)	Before action (second)	After action (second)	Reduce time (second)	Reduce time (%)
Station 1	27.20	26.58	19.67	6.91	26.00
Station 2	27.20	36.27	22.95	13.32	36.72
Station 3	27.20	28.99	18.45	10.54	36.36
Station 4	27.20	26.84	16.98	9.86	36.74
Station 5	27.20	37.40	26.94	10.46	27.97
Station 6	27.20	29.39	20.37	09.02	30.69
Station 7	27.20	26.92	20.20	06.72	24.96
Station 8	27.20	17.94	17.90	0.04	00.22
Station 9	27.20	29.52	22.51	07.01	37.77

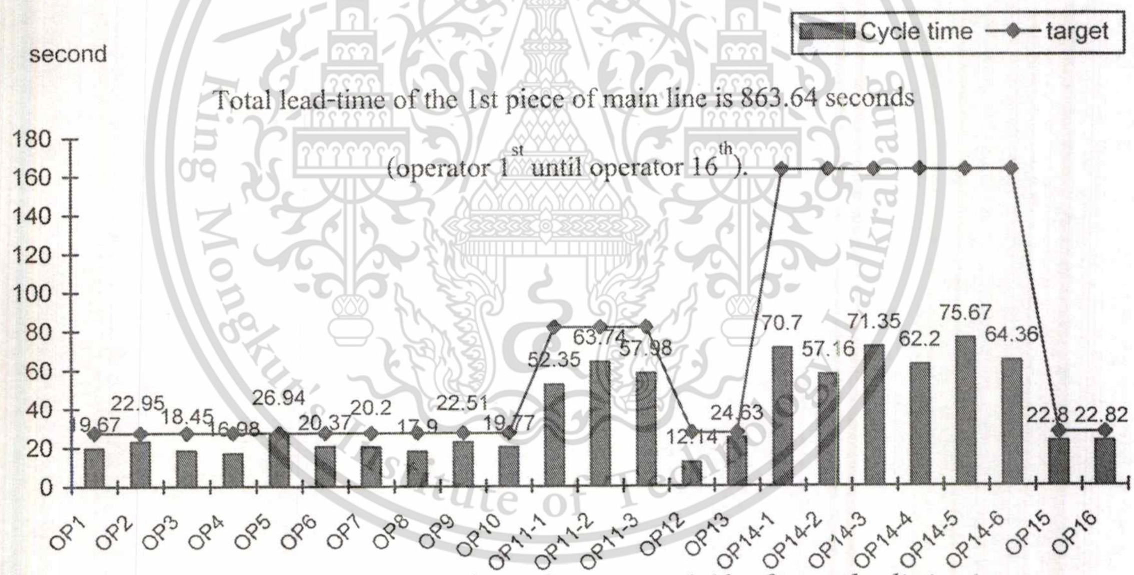

Figure 4.14 cycle time of main line, station 1-10, after muda elimination

Kaizen team has set up the update Operation standard (OS) document of working process in each station of sub-unit line and main line for training center and worker to follow after improvement. Production line leader use the new operation standard for control workers operation.

The cycle time of almost processes in figure 4.9 and 4.14 is still lower than target then line balancing and process sharing are taking place for man power reduction (Shoujinka) purpose, result is presented as in the next paragraph.

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C2. Line balancing and process sharing at sub-unit line and main line;

- Shoujinka (manpower saving) at sub-unit line on June 2010, direct man power is reduced 2 people from 12 people to 10 people per team. Therefore total man power of sub-unit line is reduced 4 people (2 teams multiple with 2 people per team). Soldering process improvement at station 7 and 8 can help to cancel man power of appearance check at station 9, and share process appearance checking to station 7 and 8. Process sharing is from station 4 to station 1, 2, 3, 5, 6, and 10. These 2 people are moved to be spare worker for multi skill training. Cycle time of each station is presented as in the figure 4.10; total lead-time of the first piece of sub-unit line is reduced from 290.02 seconds to 214.11 seconds.

Actual Takt Time of June 2010 = 21 hours * 3600 seconds / 2779 pieces = 27.20 seconds/piece

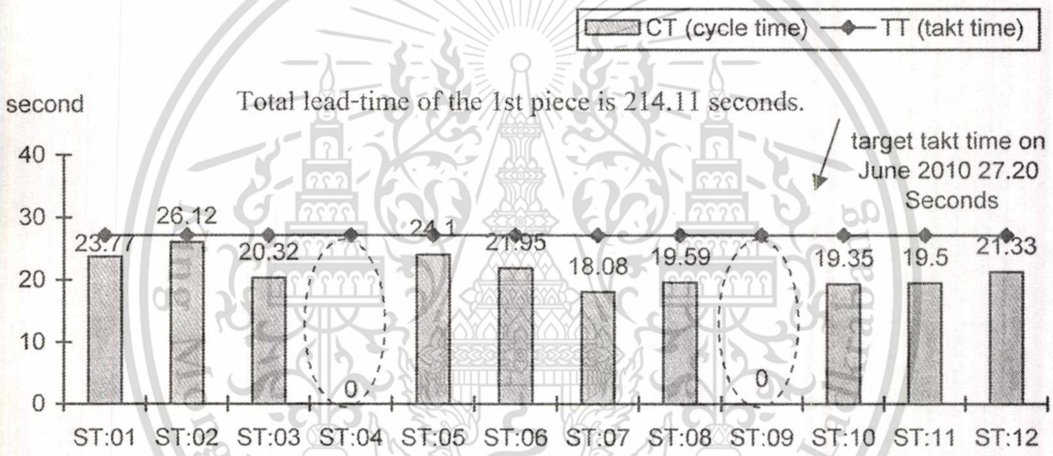

Figure 4.15 cycle time of sub-unit line of model A after process balancing

- Shoujinka (man power saving), direct manpower in main unit line is reduced total 4 people per team: 1 person at station 12, 1 person at checker process, and 2 people at cleaning process. Man power reduction from 23 people per team to be 19 people per team, and there are 2 production teams on September 2010 therefore total man power saving is 8 persons (4 people per team multiple with 2 teams).

- Shoujinka / manpower saving at mainline 1 person by process sharing of station 12 to station 6, 10 and cleaning process. Before action: cycle time of station 12 is 12.14 second which is lower than target takt time about 16.24 seconds. After action, man power of station 12 has moved to be spare worker for train multi skill.

- Shoujinka / manpower saving at checker process, before action average cycle time of checker machine is about 58.02 second which is equal to 2.04 times of main line cycle time. Total

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man power for checker process should be 2 workers but actual use is 3 workers this is cause of man power cost over target. After action, NK can reduce man power 1 person per team.

- Shoujinka / man power saving at cleaning process, before action average cycle time of cleaning process is about 66.91 seconds which is equal to 2.35 times of main line cycle time. Total man power of cleaning process should be only 3 people but factory use 6 workers this is cause of man power cost over target. After action, NK can reduce man power 2 people per team.

Cycle time of station 12, checker process and cleaning process after man power saving is presented as in the figure 4.16 below;

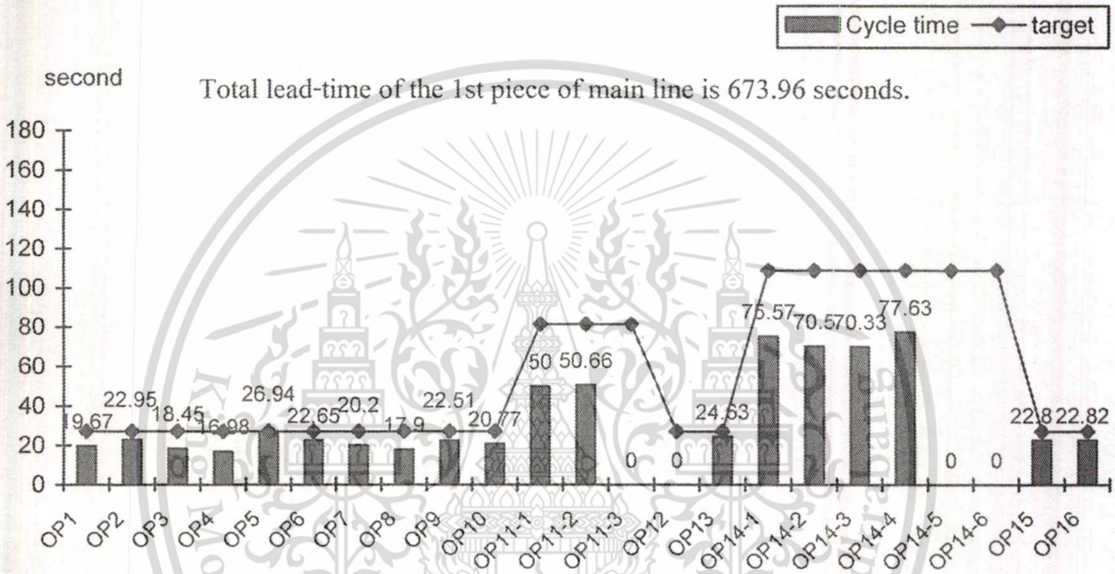

Figure 4.16 cycle time of main line, station 12, checker and cleaning after improvement.

Summary direct man power saving both sub-unit line and main line is 6 people per team or 12 people in totally. See table 4.3;

Table 4.3 Direct man power of model A all process before and after action

Process of Model A	Total man power before action (man/team)	Total man power after action (man/team)	Total man reduction / team	Total man reduction for 2 teams
Sub-unit	12	10	2	4
Main line	14	13	1	2
Checker	3	2	1	2
Cleaning	6	4	2	4
Grand total	**35**	**29**	**6**	**12**

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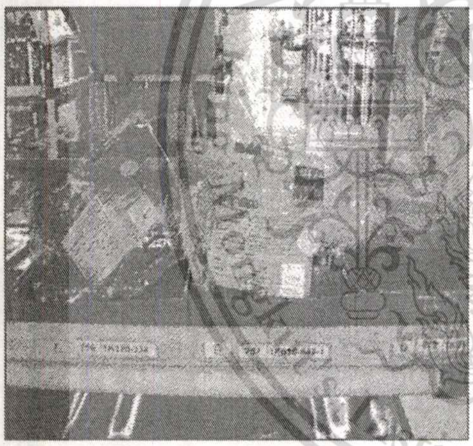
- Cost saving for Manpower of model A is 2,160 Thai Baht/day (12 people multiple with minimum labor wage year 2010, 180 Thai Baht/day).

- Area of production line model A is reduced 9 square meters from 57.15 square meters to be 48.15 square meters

D) Materials:

- Muda of Unnecessary stock at production, before action production withdraw parts from warehouse every 6 hours (about 1-2 times per shift) thus the single parts stock is about 163,902 pieces or 0.64 days. Action by setting up maximum-minimum stock of single parts for support production line, and setting up schedule withdraw parts from warehouse every 2 hours instead of every 6 hours. After action, muda of unnecessary stock has been eliminated: WIP of single parts is reduced from 163,902 pieces to be 55,610 pieces or 67 percent reduction. Total stock is reduced from 0.64 days to be 0.40 days.

Before Action After



Set up max-min level of each items.

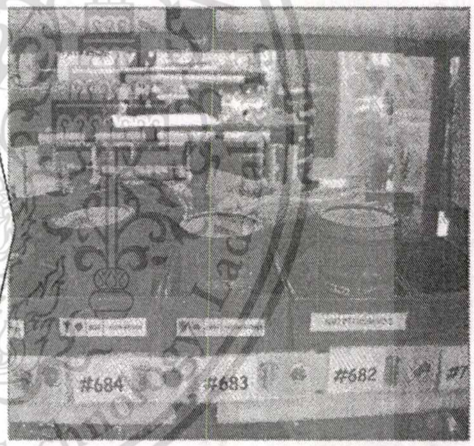


Figure 4.17a muda of parts over needed on supply cart.

Figure 4.17b parts on the supply cart after improvement.

4.1.2 Business control department result

Action results of business control department on 4 M: Man, Machine, Method, and Material which is related to warehouse section as follow details;

A) Man;

Action by training warehouse staffs 2 people about Toyota production concept => pass 100%

Warehouse staffs train workers about: 5S, Visual control, Muda, kanban => pass 80%

B) Machine;

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- Adjust shelf for keeping small parts to manage area usage efficiency, by adding layer of shelf from 4 layers to be 6 layers. Before action total shelf for keeping small parts is 20 shelves, while Parts item are increased from 5 models to be 7 models (83 items increase). After action total shelves are reduced to be only 13 shelves, space saving is 7 shelves. NK can keep parts on shelf less than before action 7 shelves; area is saved 6.72 square meters or 35% in reduction.

Before | Action | After

Grouping parts and adding shelves layer.

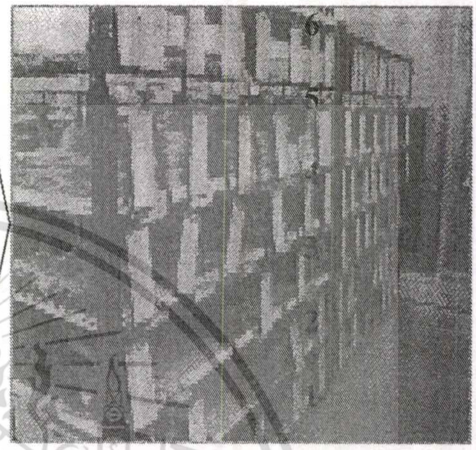
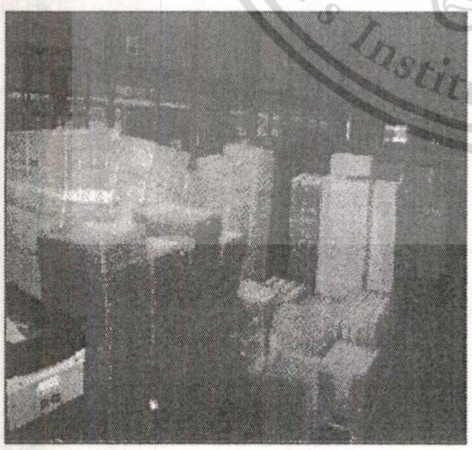


Figure 4.18a Existing shelves are 4 layers.

Figure 4.18b shelves after adjustment are 6 layers.

- Set up shelves for keep empty package return to vendors instead of put them on the pallet, visual control is not as good as other person can not know which package is belong to which vendors. After improvement, area use is reduced from 9.9 square meters to be 5.6 square meters. Area is saved 4.3 square meters or 43.43% in reduction.

Before | Action | After



Separate location by vendors.

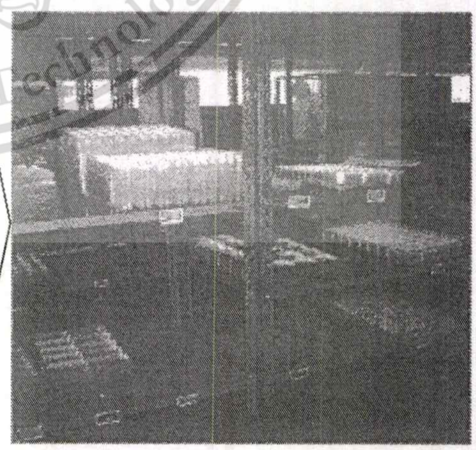


Figure 4.19a: a lot of empty package is keeping on 6 pallets.

Figure 4.19b: 7 shelves with name plate by vendors.

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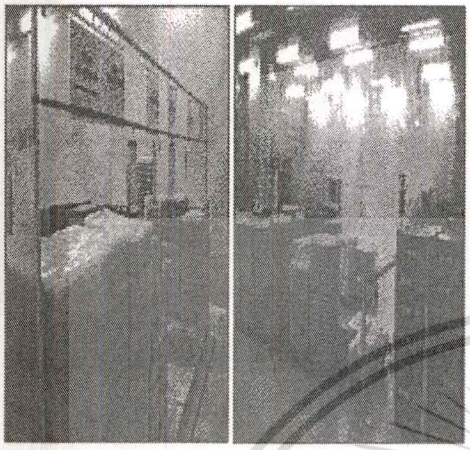
- Set up 11 rack shelves instead of 35 pallets for keep big package parts, area used is reduced from 162 square meters to be only 90 square meters, area saving 72 square meters or 44.44% in reduction.

Before | Action | After



Change layout. Set up rack shelves.

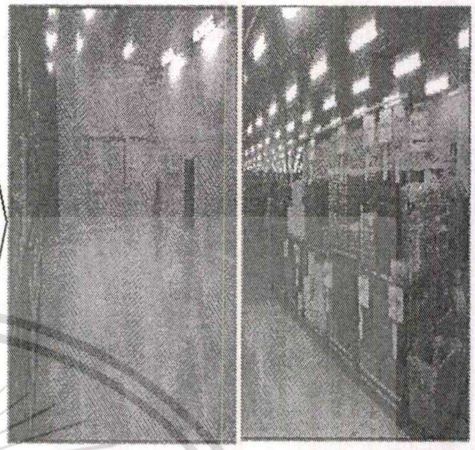


Figure 4.20a: 35 pallets of parts in clean-room.

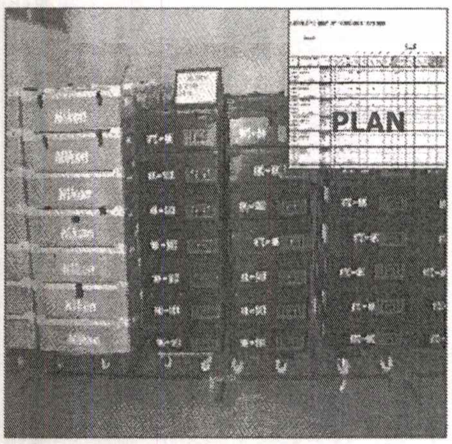
Figure 4.20b: 11 rack shelves are replaced the 35 pallets.

- Set up cart for transport injection parts from injection factory warehouse to assembly factory warehouse (internal factory), muda transportation of workers is reduced 10 minutes/ kanban round. Total time saving for internal transportation is 33.33%.

C) Method;

- Applying kanban for injection parts between assembly factory warehouse and injection factory warehouse (internal factory), before action use plan fixed safety stock at 3 days, area used is 62.28 square meters. After action by kanban cycle 1:8:1, safety stock is reduced to be 3 hours and area used is reduced to be 4.86 square meter, area saving is 57.4 square meters. Adjust kanban cycle of internal parts from 1:8:1 to be 1:21:1, safety stock is reduced to be 2 hours and area used is reduced to be 2.88 square meters, area saving 1.98 square meters.

Before | Action | After



Applying kanban, cycle is 1:8:1 then 1:20:1.

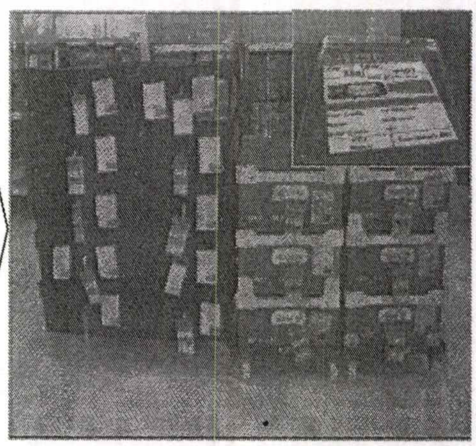


Figure 4.21a: 3 days (72 hours) of stock parts.

Figure 4.21b 0.08 days (2 hours) of stock parts.

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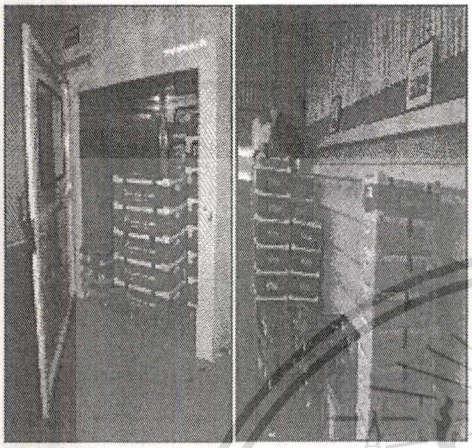
- There are about 22 packaging to be return to injection factory (internal purchase parts), area used is 7.26 square meters. After applying unpacks method at injection process, reduced package return about 22 boxes each kanban round. Area used is 1.98 square meter at assembly factory. Area saving is 5.28 square meters.

Before | Action | After



Request injection factory do unpack process.

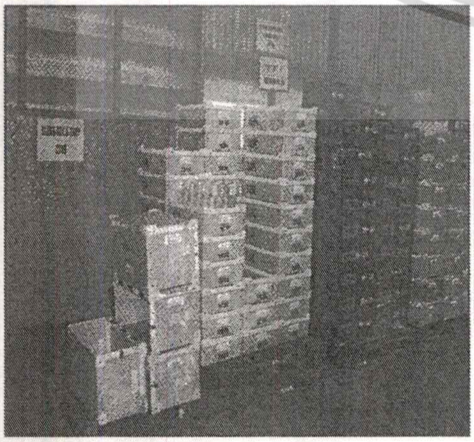
Figure 4.22a: 22 boxes to be returned each round.

Figure 4.22b: cart for support unpack parts.

- Set up standard document for warehouse workers to follow i.e. work flow of receiving and issuing parts, work instruction of receiving, storage, issuing, work instruction of load-unload finish goods, set up 5S person in charge in each warehouse location.

- Set up safety stock of finished goods package and design package preparation system, can control package quantity in each shift to support production line. There is more dust in warehouse area; worker is loss time for clean box 6.25 minutes/time (must clean about 65 boxes /hours). Set up the cabinet for keep boxes and protect boxes from dust, worker save working time to clean only top box about 15 boxes/hours; time saving is 77.86%.

Before | Action | After



Set up the cabinet for protect dust.

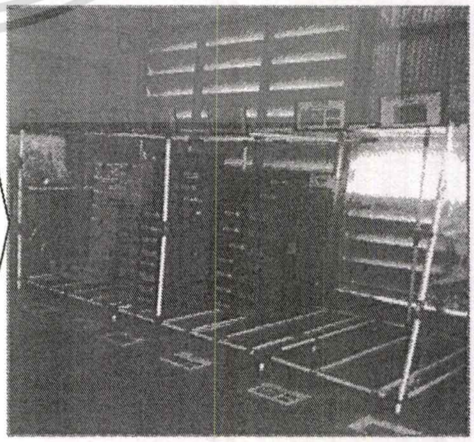


Figure 4.23a: more dust in warehouse area.

Figure 4.23b: boxes cabinet.

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- Re-layout assembly factory's warehouse: from 5 locations, (4 inside and 1 outside clean room), to be only 2 locations at 1 inside and 1 outside clean room. Warehouse area is reduced from 810 square meters to be 405 square meters or 50% inreduction. See figure 4.24 and 4.25 for reference about the total area before and after re-layout.

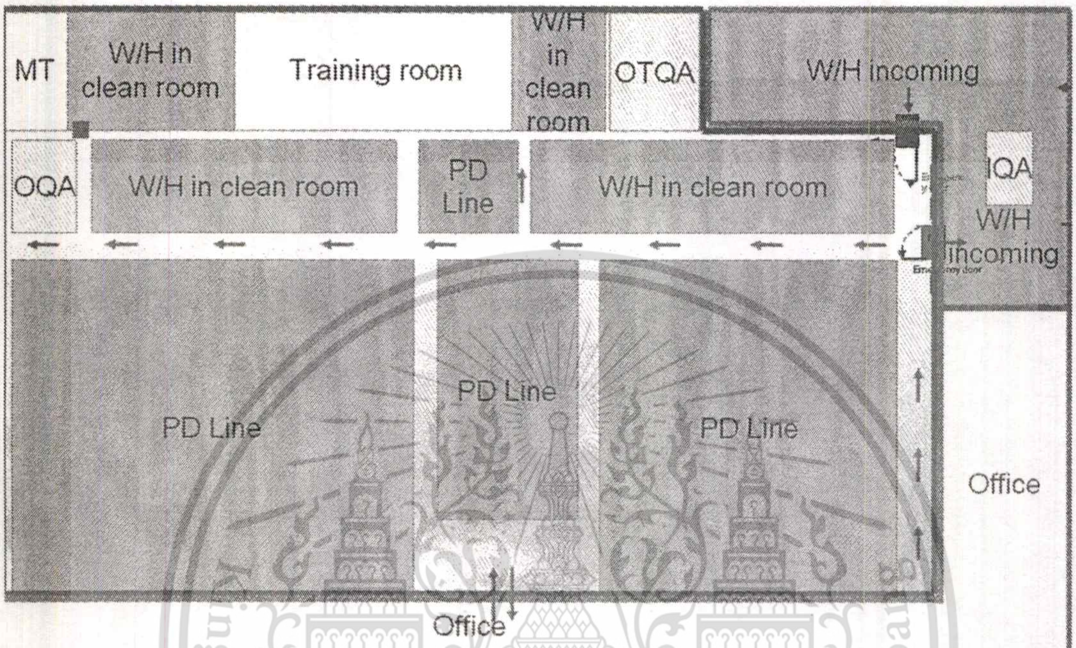

Figure 4.24 warehouse layout of assembly factory before re-layout

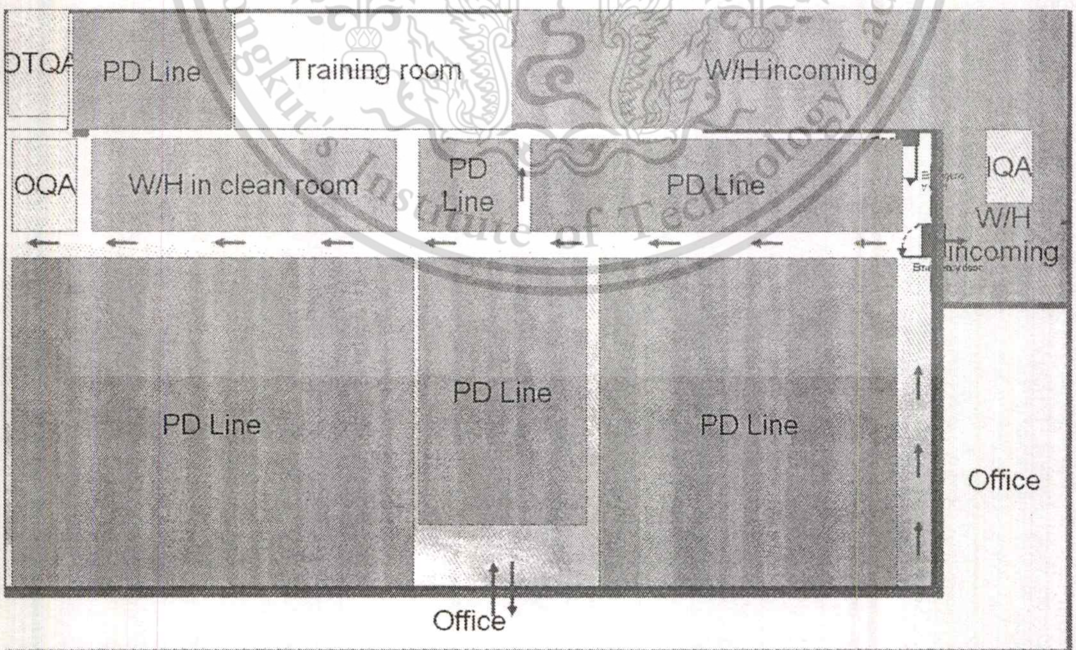

Figure 4.25 warehouse layout of assembly factory after re-layout

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D) Materials;

- Muda of unnecessary stock has been eliminated;

- Set up safety stock of non-kanban parts and re-layout warehouse area, stock is reduced from 10 days to be 8 days.

- Applying kanban between assembly factory warehouse and DC warehouse for the big package parts. Stock of kanban parts from supplier (external) at assembly factory warehouse is reduced from 10 days to be 2 days.

- Applying kanban between assembly factory production line and injection factory warehouse, change from assembly warehouse to be direct to assembly production line, stock of Kanban parts (injection parts) is reduced from 2 hours to be 1.5 hours.

4.1.3 Quality Assurance department result

Action results of quality assurance department on 4M; Man, Machine, Method and Material are as follow;

A) Man;

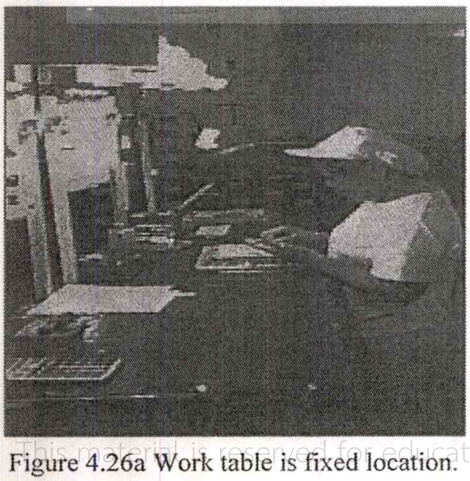
- Training to workers and identify by skill card, after action 10 people can be supporter with multi skill.

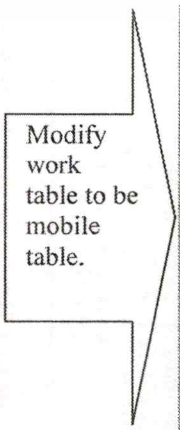
B) Machine;

- Set up work sheet for control machine and tools in line then monitoring by X-bar and R-chart.

- Set up mobile work table, muda movement of IQA workers is reduced from walking back and forth between work table and parts to be inspected. Average time saving is 51 second from 102 second per item or 50%. See figure 4.26a and 4.26b for reference.

Before Action After





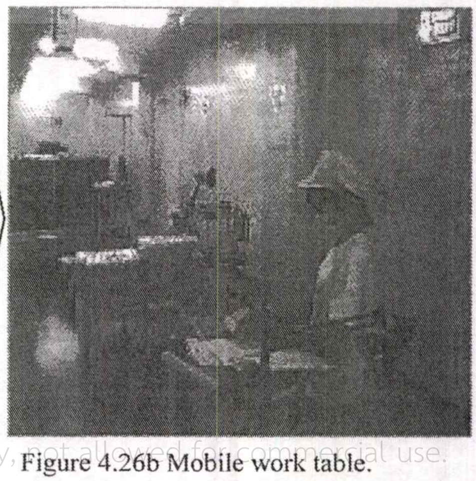


Figure 4.26a Work table is fixed location. Figure 4.26b Mobile work table.

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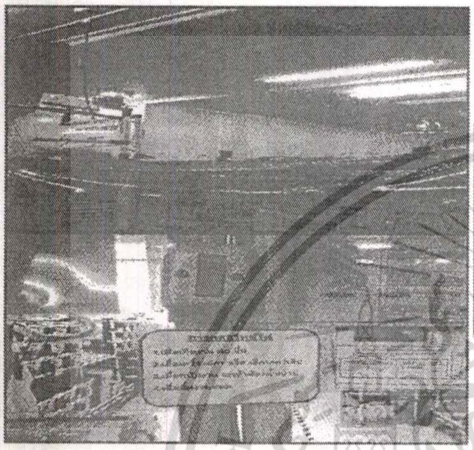
- Muda waiting has been eliminated: before action the andon is light but take time to solve the problem in line about 10 minutes. As line leader has to go to line for check the problem then inform to the relate section to solve problem of man, machine, method or material. After action by set up the color for andon light, time spend to take action when the production line stop is decreased from 10 minutes to 3-5 minutes or 50 - 60 percent reduction. See figure 4.27a and 4.27b for reference.

Before | Action | After



Set up color for andon light.

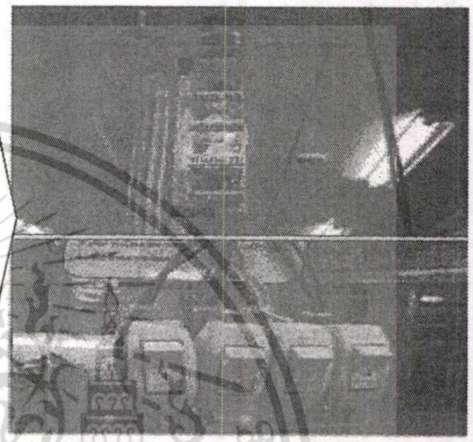


Figure 4.27a andon light is turned on in red color.

Figure 4.27b andon light in different 4 colors: blue, green, orange and red.

C) Method;

- Re-layout of IQA (incoming-quality-assurance), before action total area is 25 square meters after action total area is 10 square meters or 15 square meter reduction (60%).

- Applying standard work for analyze the working process of IQA, before action total muda (waste) time is 148 seconds, after action total muda (waste) time is 65 seconds.

- After develop the mobile work table for IQA workers found that workers still have muda in their work as they do not know the priority of parts to be inspected. Loss time is about 20 seconds/item to find the parts. Kaizen team do visual control by tag identify status of part waiting inspection at incoming area for reduce muda of waiting from unclear information whether it has already inspected or it has not yet inspection, and set up coloring tag to identify parts priority to be inspected: red tag is mean must be inspected within 1 hour, yellow is mean must be inspected within 4 hours and lastly green tag is mean not urgent, can be inspected within 6 hours. Time is saved about 6 seconds/item or 30% in reduction. See figure 4.28a and 4.28 for compare before and after improvement.

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Before Action After

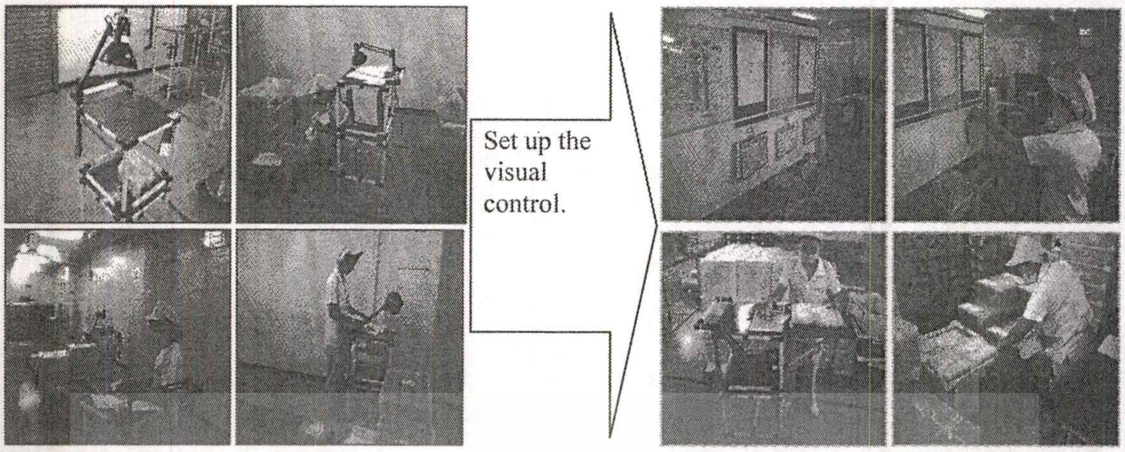

Figure 4.28a IQA workers do not know priority of the parts.

Figure 4.28b Prioritize queue by Red, Yellow and Green tag.

- Set up limit sample for help worker to inspect and make judgment on non-confromance parts by themselves, follow Jikoutei Kanketsu concept (building up quality mind set), not let the non-conformance parts leak to the next process.

- Set up "Poka-Yoke" tools for help protect the mistake operation. Non-conformance product of model A from "GAP problem" can be reduced from 21 pieces in August 2010 to be 1 piece in September 2010. See figure 4.29a and 4.29b for example of "Pokayoke" for the 3 pin gauges to be used in process and the identify box is not clear, improvement by coloring the pin boxes to be green orange and light blue.

Before Action After

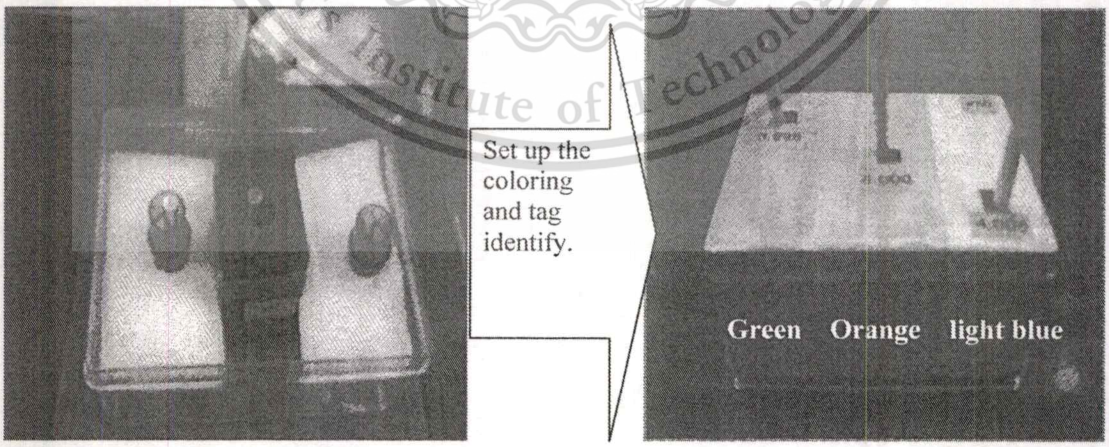

Figure 4.29a the existing pin gauges box.

Figure 4.29b Pokayoke pin gauge box by coloring: green, orange and light blue.

- Reduce man power of inspection parts by apply the switching lot concept, before action if inspection part at normal level total man power is 5 people as IQA has to check parts totally

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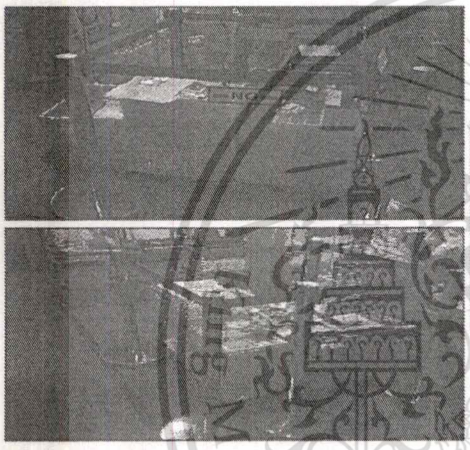
125 pieces. After action, IQA has to check parts only 80 pieces and total man power is only 3 people.

D) Material;

- Set up list for control the non-conformance parts information between Quality Assurance department and Business Control department. Before action, there is no any list to control the non-conformance parts and cause stock different when process physical inventory check at the end month. After action, IQA record data of non-conformance parts in to the list and Business control department can check the list for contact to vendors.

Before | Action | After



Set up the list of non-good parts.

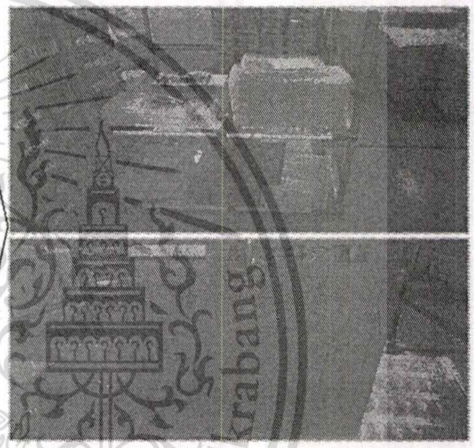
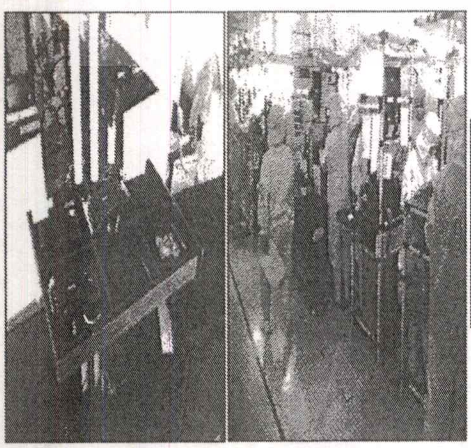


Figure 4.30a area of non-conformance parts without list information.

Figure 4.30b list information of non-conformance parts.

- Set up rule for record non-conformance parts in production process, to take action faster and improve good ratio. As non-conformance part is affected to less output than target. Set up board for monitoring and solve problem by daily, see figure 4.31a and 4.31b.

Before | Action | After



Set up the board of non-conformance in process.

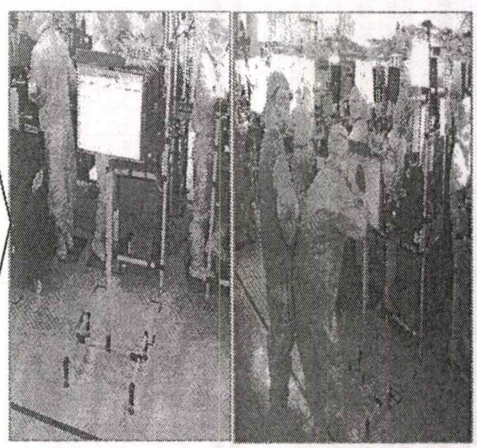


Figure 4.31a non-conformance unit in assembly process.

Figure 4.31b board for action of non-conformance unit.

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4.1.4 Customer Evaluation Score

See Table 4.4 and 4.5 for customer evaluation score period January 2010 to December 2010. From table 4.4, the total score is decreased from 74.5 points to be 68 points and 63 points respectively from January to June and September, after project end in September the total score is increased to be 72.5 points in December. The quality of the product score is increased back to the 20.5 point.

Table 4.4 customer evaluation score January – December 2010

Evaluation topics	Full score	Result 2010			
		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1.The Delivery of the product	42	35	35	35	35
2.The quality of the product	36	20.5	14	9	20.5
3.Documentation support	10	10	10	10	10
4.Sales support & co-operation	12	9	9	9	7
Total score	**100**	**74.5**	**68**	**63**	**72.5**
Grade		C	C	C	C

From table 4.5, details of customer evaluation score; the quality of the product score is increased from 9 points in September back to 20.5 points in December which is related to the topic 2.1 defective rate score in each month is increased from 6.5 points in September to be 13 points in December and topic 2.2 the reply of non-conforming level is increased from 2.5 points in September to be 7.5 points in December.

Table 4.5 Details of customer evaluation score January – December 2010

Evaluation topics	Full score	Result 2010			
		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1.The Delivery of the product	**42**	**35**	**35**	**35**	**35**
1.1. Delivery 100% on time	28	21	21	21	21
1.2. Delivery accuracy	10	10	10	10	10
1.3. Packaging of the product is completed	4	4	4	4	4
2.The quality of the product	**36**	**20.5**	**14**	**9**	**20.5**
2.1 Defective rate in each month	26	13	6.5	6.5	13
2.2 The reply of non-conforming level	10	7.5	7.5	2.5	7.5
3.Documentation support	**10**	**10**	**10**	**10**	**10**
3.1 correctness of Tax invoice or shipping document, including the unit price and description of parts	10	10	10	10	10
4.Sales support & co-operation	**12**	**9**	**9**	**9**	**7**
4.1 Speedy of response to customer inquiry	4	4	4	4	3
4.2 Cost reduction co-operation	4	1	1	1	1
4.3 The manner of contact person	4	4	4	4	3

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Table 4.6 is presented the customer evaluation score details in quality topic of January to December 2010 which is related to the topics 2 of table 4.4 as above. Topic 1: in process claim result, score is decreased from 44 points in 1st quarter (Jan-Mar) to be 36.8 points in 2nd quarter (Apr-Jun), 27.4 point in 3rd quarter (Jul-Sep) and the score is increased to be 46.4 point in 4th quarter (Oct-Dec) respectively.

Table 4.6 Customer evaluation score details in Quality Topic January – December 2010

Outsource Quality Assurance Evaluation		**Full score**	**Result 2010**			
Evaluation topics	**Criteria**		**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
1.In process claim result	If > 0.5% = 0 point	70	44	36.8	27.4	46.4
2.Defective report delay	Delay 1 report = - 1 point	10	10	10	0	10
3.Co-operation for take action	Main in charger	10	8	8	9	8
4.E-mail feed back respond	Main in charger	5	4	3	4	4
5. Visitors receive ordially	Main in charger	5	4	4	3	4
Total score		**100**	**70**	**61.8**	**43.4**	**72.4**

Table 4.7 is presented delivery performance score of all models, on time delivery percent is 97.36 in 1st quarter (Jan-Mar), 99.99 in 2nd quarter (Apr-Jun), 99.66 in 3rd quarter (Jul-Sep) and 94.04 in 4th quarter (Oct-Dec) while table 4.8 is presented delivery performance score of model A in percentage which is 97.47 in 1st quarter (Jan-Mar), 100 in 2nd quarter (Apr-Jun), 99.80 in 3rd quarter (Jul-Sep) and 98.36 in 4th quarter (Oct-Dec). Even delivery performance score of on time delivery of all model is trend to be decreased but the model A that team improvement do action by apply TQM (Total Quality Management) and TPS (Toyota Production System) is get better score.

Table 4.7 delivery performances of all models (retrieved from customer evaluation result)

Delivery of all models Delay 2010	**Result 2010**			
	Jan-Mar	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
Total ship quantity	24650	33474	38556	51150
Total delay quantity	650	1	130	3046
Delay %	2.64%	0.003%	0.34%	5.96%
Ontime %	97.36%	99.997%	99.66%	94.04%
Grade	B	B	B	B

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Table 4.8 delivery performance of model A year 2010 (company secondary data)

Delivery of model A Delay year 2010	Result 2010			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Total ship quantity (kanban)	7282	9211	5904	4151
Total delay quantity (kanban)	184	0	12	68
Delay %	2.53%	0.00%	0.20%	1.64%
Ontime %	97.47%	100.00%	99.80%	98.36%
Grade	B	B	B	B

Shokuba Shindan is trainer evaluation assembly factory's performance in basic production topics; 5Ss, safety, productivity, quality, cost, and delivery on March 2010, May 2010, June 2010, August 2010 and October 2010 totally 5 times. Result is presented as in table 4.9 and figure 4.32 as below. Target score in each topic is 75 points for 5Ss, safety, quality, cost and delivery respectively. Only productivity that target score is 60 points. Score of each topic is trend to be increased; score of 5Ss topic is increased from 38 points on March to be 73 points in October. Score of safety topic is increased from 55 points in March to be 72 points in October. Score of productivity topic is increased from 40 points in March to be 57 points in October. Score of quality topic is increased from 55 points in March to be 68 points in October. Score of cost topic is increased from 55 points in March to be 73 points in October. And lastly score of delivery topic is increased from 40 points in March to be 70 points in October.

Table 4.9 Basic production score of assembly factory by trainers' evaluation.

Topics	5Ss	Safety	productivity	quality	cost	delivery
Target score	75	75	60	75	75	75
Score March 2010	38	55	40	55	55	40
Score May 2010	59	60	40	60	60	45
Score June 2010	67	68	50	58	70	56
Score August 2010	71	70	56	65	68	63
Score October 2010	73	72	57	68	73	70

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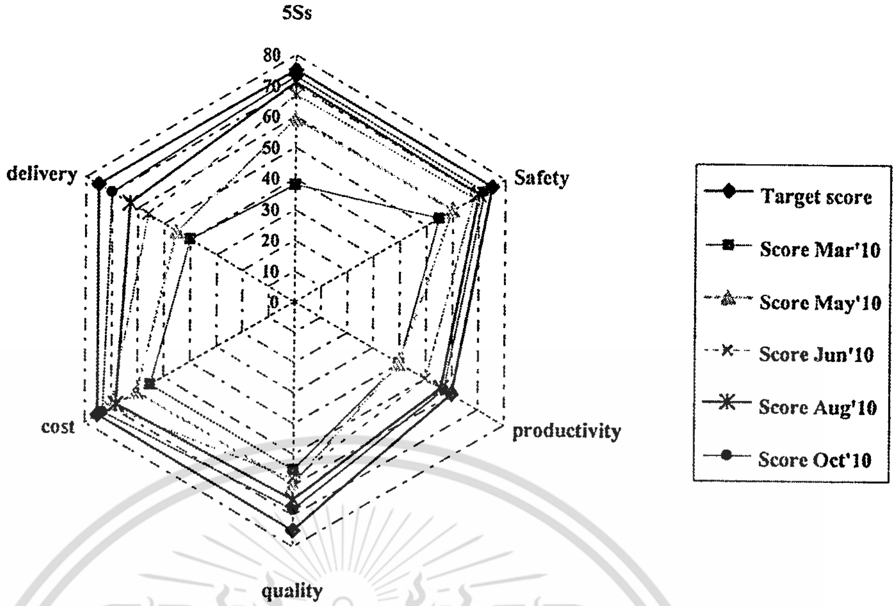

Figure 4.32 Radar charts of Basic production score by trainers' evaluation.

4.2 Key Performance Index (KPI) result;

From all the improvement activities as describe above, there are 3 Key performance indexes result presented as follow;

4.2.1 50% of non-conformance products reduction: target by decreasing from 1,394 pieces to be 687 pieces.

Result after project improvement in September 2010, total defective or non-conformance product is decreased totally 336 pieces from 1394 pieces to be 1058 pieces or 24.1 percent in reduction. Good ratio is increased from 97.12 percent in period Jan-Mar 2010 to be 98.37 percent in period Jul-Sep 2010. See table 4.10 for the good ratio data.

Table 4.10 Good ratio of model A, January – December 2010

Good ratio model A year 2010	Jan - Mar 2010	Apr - Jun 2010	Jul - Sep 2010	Oct - Dec 2010
Out put (pieces)	220054	259678	152239	96697
Non good (pieces)	6341	4207	2478	3378
Non good %	2.88%	1.62%	1.63%	3.49%
Good ratio	97.12%	98.38%	98.37%	96.51%

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4.2.2 50% of productivity up: target by increasing OPM (Operation Performance) from 40% to be 60%.

Result of muda elimination, line balancing and man power saving is affected and increase the percentage of Operation Performance or OPM from 40.03% on April 2010 to be 49.30% on September 2010 or 21.21% increased.

$$\%OPM = \frac{S\tan dardtime * output / day * 100}{workingtime * directmanpower} \quad \ldots\ldots\ldots\ldots\ldots\ldots equation\ 2.1$$

%OPM (April 2010)

$$= \frac{8.7\text{ minutes } * 4000\text{pcs} * 100}{21\text{ hours} * 60\text{minutes} * 69\text{persons}}$$

= 40.03% (4,000 pcs/ 3 teams or 1,333 pcs/team)

%OPM (September 2010)

$$= \frac{8.7\text{ minutes} * 2713\text{pcs} * 100}{21\text{ hours} * 60\text{minutes} * 38\text{persons}}$$

= 49.30% (2,713 pcs/ 2 teams or 1,656 pcs/team)

4.2.3 50% of Time and Space Saving: target by reducing WIP (Work In Process) to meet customer standard from 7.0 days to 3.5 days lead-time

After finishing project improvement on September 2010, total stock of all process from customer supply process until customer receives finish goods process can be reduced from 7 days to be 5.27 days lead-time or 1.73 days in reduction which is equal to 24.71 percent. WIP (work in process) of single parts is reduced from 1.35 days to be 1.31 days and Finish goods is reduced from 5.01 days to be 3.69 days total WIP is reduced from 6.36 days to be 5 days (21.38 percent reduction). Stock quantity of customer's parts of each process after project improvement is presented in figure 4.33 and table 4.11

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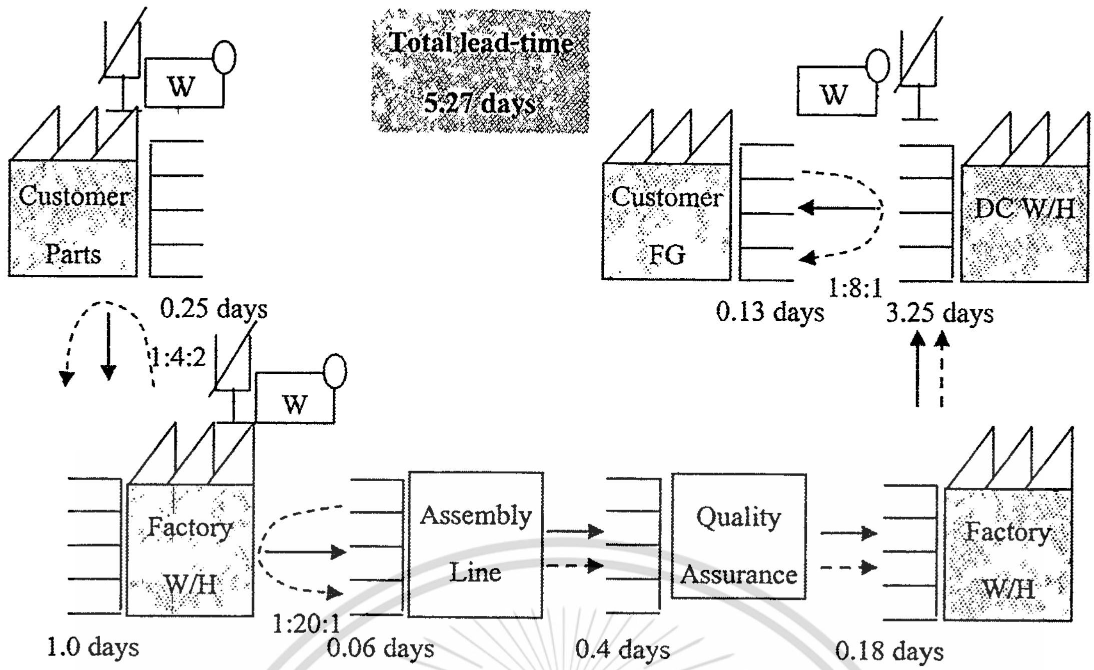

Figure 4.33 flow base manufacturing sample of stock parts supply

Table 4.11 comparisons of stock target and actual stock before and after project improvement.

Process	Target stock (Days)	Actual stock (Days)	
		Before (Apr'10)	After (Sep'10)
Customer supply parts - Factory warehouse (Kanban cycle 1:2:1)	0.50	0.50	0.25
Factory warehouse - Assembly line (Kanban cycle 1:20:1)	1.00	1.16	1.06
Assembly line - Quality assurance	0.15	0.33	0.4
Quality assurance - FG warehouse	0.35	0.48	0.18
FG warehouse - DC warehouse	1.35	4.40	3.25
DC warehouse - customer FG warehouse (Kanban cycle 1:8:1)	0.15	0.13	0.13
Total	**3.50**	**7.00**	**5.27**

- Total warehouse area of its own warehouse and DC warehouse is not changed but proportion of its own warehouse and DC warehouse is changed;

- Own warehouse in assembly factory circumstance; is decreased from 810 square meters to be 405 square meters or decrease 405 square meters (50 percent reduction).

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- Rental Distribution Center (DC) warehouse in Ayudthaya; is increased from 195 square meters to be 600 square meters or increased 405 square meters (207.7 percent increasing). See table 4.12 for reference.

Table 4.12 warehouse area before and after project improvement

Warehouse area	Before	After	After - Before	percent
1. NK warehouse (m2)	810	405	-405	-50.00%
2. Distribution Center (m2)	195	600	405	207.7%
3. Total area (m2)	1005	1005	0	0.0%

This is caused of the increasing of single parts items totally 98 items from 281 items to be 379 items. Anyway the rate of area using per item is decreased from 3.58 square meters to be 2.65 square meters which is equal to 0.92 square meters decreases (25.86 percent reduction). See table 4.13 for reference.

Table 4.13 warehouse area use per parts item before and after project improvement

Warehouse area	Before	After	After - Before	percent
1. Total area (m2)	1005	1005	0	0.0%
2. Parts total (items)	281	379	98	34.88%
3. Area use/item (m2)	3.58	2.65	-0.92	-25.86%

Cost saving for warehouse space is 148,961.74 Baht

= rental area rate * total item*area use saving of each item.

= 425 THB/m2 * 379 items * -0.92 m2 saving/item

In the other hand, if the rate of area using per item is still 3.58 square meters company has to rent more 350.50 m2 of warehouse space to support the additional parts 98 items (3.58 m2 * 98 item = 350.50 m2). See table 4.14 for more details of area cost per parts item;

Table 4.14 warehouse cost per parts item before and after project improvement

Warehouse area	Before	After	After - Before	percent
1. Area cost (THB/m2)	425	425	0	0.00%
2. Area use/item (m2)	3.58	2.65	-0.92	-25.86%
3. Area cost/item (THB)	1,520.02	1,126.98	(393.04)	-25.86%

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Chapter 5

Conclusion and recommendation

5.1 Conclusion

After 6 months lead time of the improvement project at model A, an assembly factory can do improvement at each department by applying PDSA, Ishikawa diagram, Pareto chart to analyze problems and TPS concept (5S, 7Muda, Standard work, Kanban, Kaizen, Just In time and Jidoka) to solve problems and improve company performance to satisfy customer evaluation and management policy (KPI) in Production department, Business control department and Quality assurance department as follow;

1) Man power skills at production both theoretical and practical in soldering skill and cleaning skill to line leader, sub leader and workers of model A. Spare workers of special skills can be set up to achieve 7 % per team. TPS knowledge is trained to team members and basic TPS such as 5S, visual control, Muda and kanban are trained to some workers. 10 Quality assurance workers can be supporter with multi skills. 2 workers of IQA is saved (Shojinka) by applying switching lot concept. Man power absent rate of production can be reduced from 6.30% in November 2010 to be 3.02% in April 2011.

2) Machine break down can be reduced from 23.78 hours in November 2011 to be 7.88 hours in April 2011. Wastes or Muda of waiting time is reduced 5-7 minutes from Andon light improvement.

3) Method: Wastes or Muda of unnecessary movement is eliminated from assembly process method of sub-unit line and main-line; lead time of the 1st piece of sub-unit line can be reduced from 347.56 seconds to be 290.02 seconds on May 2012. Lead time of the 1st piece of main line can be reduced from 932.10 seconds to be 863.64 seconds in June 2010. After that team members has balancing the process which can reduce the lead time of the 1st piece of sub-unit line from 290.02 seconds to be 214.11 seconds in June 2010 and reduce lead time of the 1st piece of main line from 863.64 seconds to be 673.96 seconds in September 2010 respectively. Total direct man power saving (Shoujinka) from process balancing both sub-unit line and main line is 12 people (6 people per team multiple with 2 teams). At IQA: 51 seconds per item are saved from inspection process by mobile work table and 6 seconds per item are saved from coloring tag of parts to be inspected. Wastes or Muda of non-conformance product in production line can be reduced, for

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example the non-conformance of GAP problem can be reduced from 21 pieces in August 2010 to be 1 piece in September 2010 by applying Pokayoke tools. Area efficiency improvement by 6.72 square meters reduction from setting up the shelves layers to keep parts, 4.3 square meters reduction from package keeping shelves, 72 square meters reduction from setting up 11 rack shelves instead of 35 pallets, 7.26 square meters reduction from applying kanban of internal factory parts between assembly factory and injection factory, and lastly 405 square meters of warehouse area reduction from re-layout (combine warehouse from 5 locations to be 2 locations inside the assembly factory).

4) Material: Wastes or Muda of unnecessary stock in production line can be reduced from 0.64 days to be 0.40 days by set up the Max-Min and working method of the supply cart. While the wastes or Muda of unnecessary stock at warehouse of non-kanban part is reduced from 10 days to be 8 days by setting up safety stock policy. Big package parts stock is reduced from 10 days to be 2 days by applying withdrawal kanban or conveyance kanban between its own warehouse and DC warehouse. Stock of internal factory parts between assembly factory and injection factory is reduced from 3 days to be 1.5 hours by applying kanban.

Further than the 4M improvement, customer evaluation score in quality topic is also increased from 9 points in September 2010 to be 20.5 point in December 2010 as the defective rate is improved and in process claim result is also improved. Delivery performance of model A that team improvement do action is get better score than the other models. Final score in December 2010 of an assembly factory is 72.5 points which is higher than 60 points "Authorized is continued", the assembly factory can continue business with customer. Result of Shokuba Shindan or trainer evaluation in basics production topics: 5S, safety, productivity, quality, cost and delivery from March 2010 to October 2010 also tend to increase respectively.

Reviewing on the KPI target result of the improvement project, all the 3 topics which are 50% of non-conformance products reduction, 50% of productivity up by increment of OPM (Operation Performance) and 50% of time and space saving by WIP (Work in process) reduction are also improved. Non-conformance products are reduced from 1,394 pieces in to be 1,058 pieces or 24.1% in reduction. Productivity is increased as the OPM% is increased from 40.03% to be 49.30% or 21.21% increment. WIP (work in process) of parts supply by customer in an assembly factory is reduced from 7 days to be 5.27 days lead time or 1.73 days (24.1%) in reduction.

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It can be summarized that applying Ishikawa diagram is helping team member to analyze problem as Ishikawa diagram can help team pointed out the cause and effect of the poor quality, high cost and delayed delivery to the customer. While the Pareto chart is helping team member to prioritize the important problem to be solved as improvement project has been limited 6 months lead time. Applying PDSA, Perry Johnson method and TPS (Toyota Production System) are helping team members in the business performance improvement of an organization in Quality, Cost and Delivery. Anyway all related parties within an assembly factory should help each other and act in the same way to achieve the same goal unless it will cause unsatisfied result or failed in implement the project. Conflicting and political people inside an organization can cause delaying in any improvement step. Team members should be more patient and keep going on achieving the target, maintain the Kaizen mind and empower each other during improvement activities. Communication and public relation for the improvement activities are necessary for both Top down and bottom up, to make clear understand or point of view, then all related parties know and give co-operation to the team members.

5.2 Recommendation

1. The project improvement is only applied to one product model (model A), and withdrawal KANBAN is not applied in full processes. An assembly factory should apply KANBAN to the missing processes which are finished goods process between quality assurance and production line, finished goods process between warehouse and quality assurance, finished goods process between DC warehouse and factory warehouse, parts process between vendors and DC warehouse. Further more, pull system should be expanded to all the product models. These missing processes causes incomplete pull system loop. The assembly factory did not apply production Kanban to the production process yet. See figure 5.1 for the KANBAN flow of electronics assembly factory as below.

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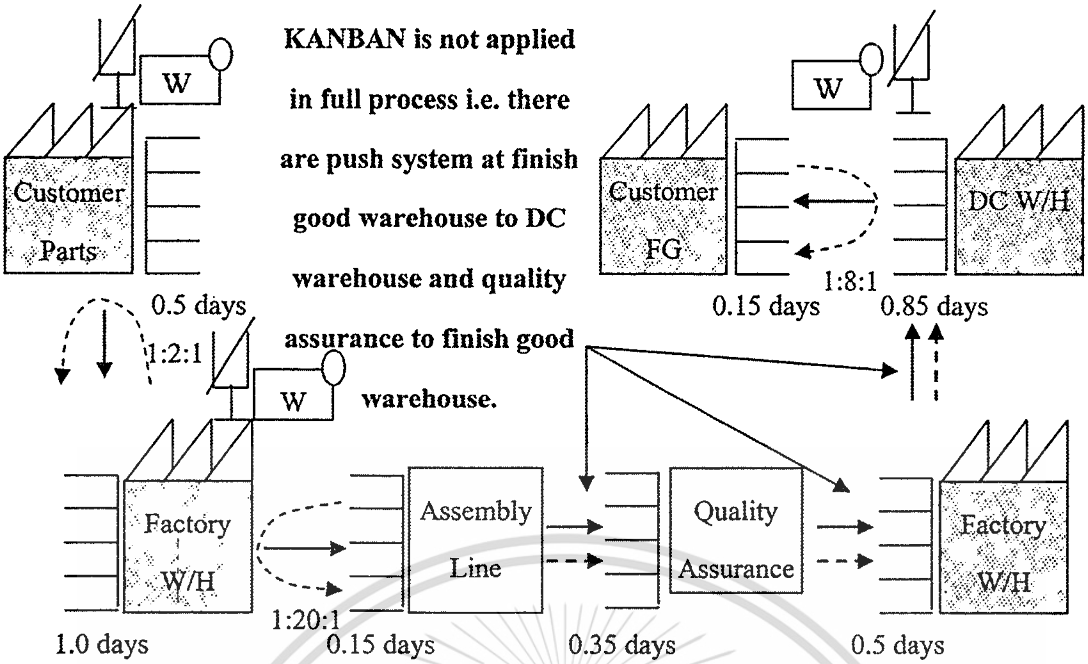

Figure 5.1 KANBAN flows of electronics assembly factory

2. The improvement of Business control department focuses only on warehouse activity and is not improvement the purchasing and delivery activities. An assembly factory should consider integrating logistics activities within an organization by expanding the improvement on these 2 sections (purchasing and delivery) in the same way of warehouse improvement;

- Set up purchasing policy to be more frequency shipment than 2 shipments per month.
- Increase delivery schedule from factory to DC warehouse or co-operate with customer to arrange milk run shipment from factory to customer warehouse.

By doing these total rental area at DC warehouse can be decreased for both parts keeping area and finish goods keeping area thus rental warehouse cost will be decreased as well. Anyway, the assembly factory should considered total cost of logistic activities which are rental warehouse cost, transportation cost, Inventory carrying cost and administration cost. As the cost analysis is relevant to logistics management in order to operate all major components resources of a logistics system (see figure 5.2). The figure presents from procurement, to warehousing, to transportation and information systems; and they involve human, capital, and material inputs. Cost analysis can be used to understand the level of resources that are required to operate a logistics system, with the goal of maximizing the desired performance of the system while minimizing the cost of resources. [21]

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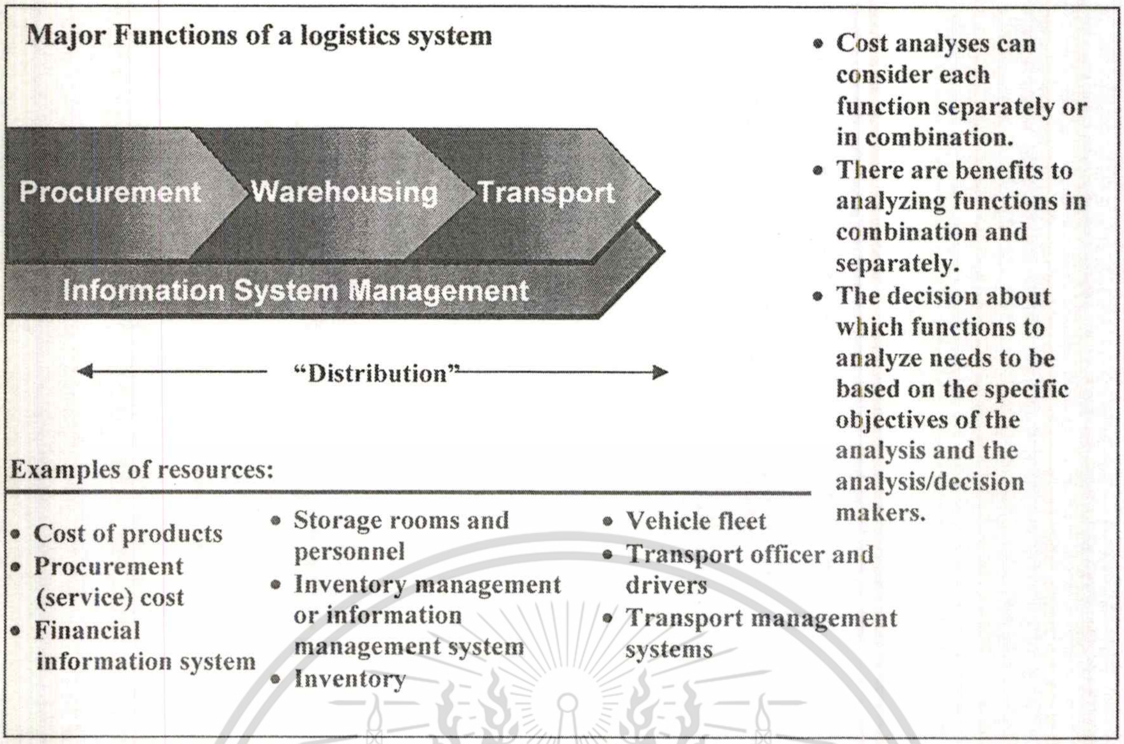

Figure 5.2: Cost associated with logistics management [4]

3. The project result is only internal the electronics assembly factory, the factory should compare result with competitors or bench mark with the others for further improvement and should keep on improvement by following the concept continuous improvement.

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