Chapter 6
Result Comparison and Conclusion

The factory implemented new manufacturing environment and redesign many processes in January 2003. The planning started since end of year 2002 (November). According to the implementations, the factory improves vastly in many aspects such as environment, methods, quality issues, and especially base systematically on time compression. It is emphasizing on areas of problems and resolve directly to the causes. Some issues are intangible such as human, which is hard to measure in terms of numerical except for letting them able to share further comments and opinions on the new process redesign.

1. Processes and Assembly Time Reduction

1.1 Comparative Results

To ensure that redesign implementations really take effect and providing acceptable results or not, the team initially compared former process (assembly) activities with the new one. The method is done by finding total production lead-time in three aspects; process operation time, sub-assembly operation time, and final assembly operation time used for a comparison. The measurement only involve with internal activities within stations or cells. The team summarized every elements of operations used to produce the product described in chapter 4 – 5 together.

Table 6-1a; Operation time for each activity in producing fan coil units (sets)

Fan Coil Unit	
Processes Station	
Traditional System	**Redesign System**
4,105 Seconds	**2,823 Seconds**
Assembly Station	
Traditional System	**Redesign System**
1,444 Seconds	**1,138 Seconds**

Table 6-1b; Operation time for each activity in producing condensing units (sets)

Condensing Unit	
Processes Station	
Traditional System	Redesign System
3,304 Seconds	2,841 Seconds
Assembly Station	
Traditional System	Redesign System
1,531 Seconds	824 Seconds

Figure 6-1a illustrated diagram showing the processes time of the former system compare with redesign system while 6-1b illustrated another diagram showing sub-assembly and final assembly time between both production systems. Figure 6-2 represented the overall picture.

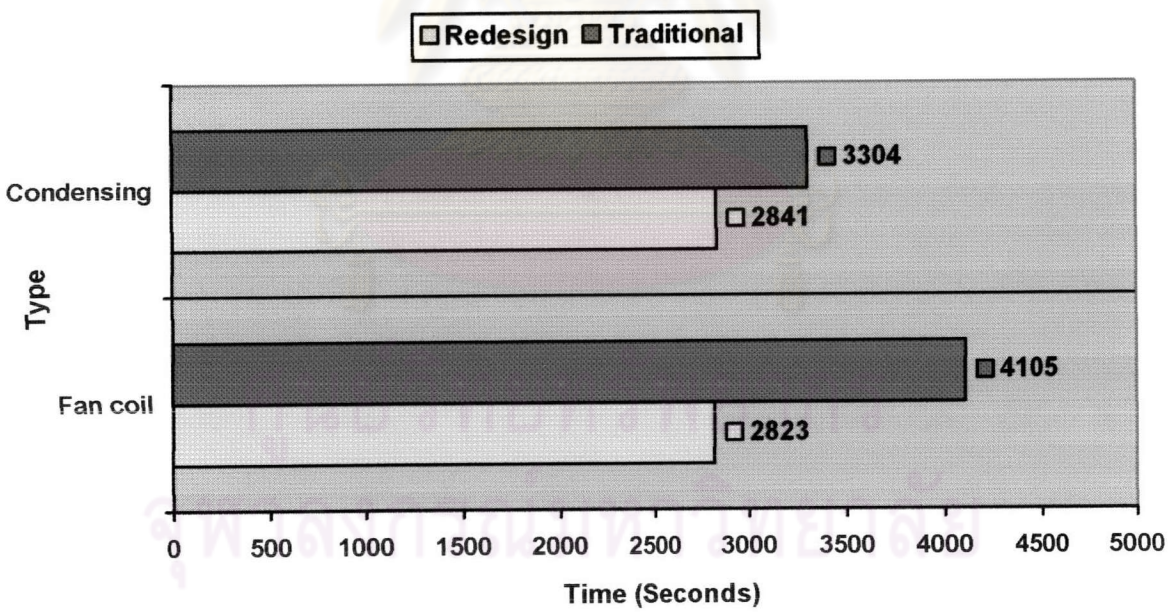

Figure 6-1a; Process time of traditional and redesign system

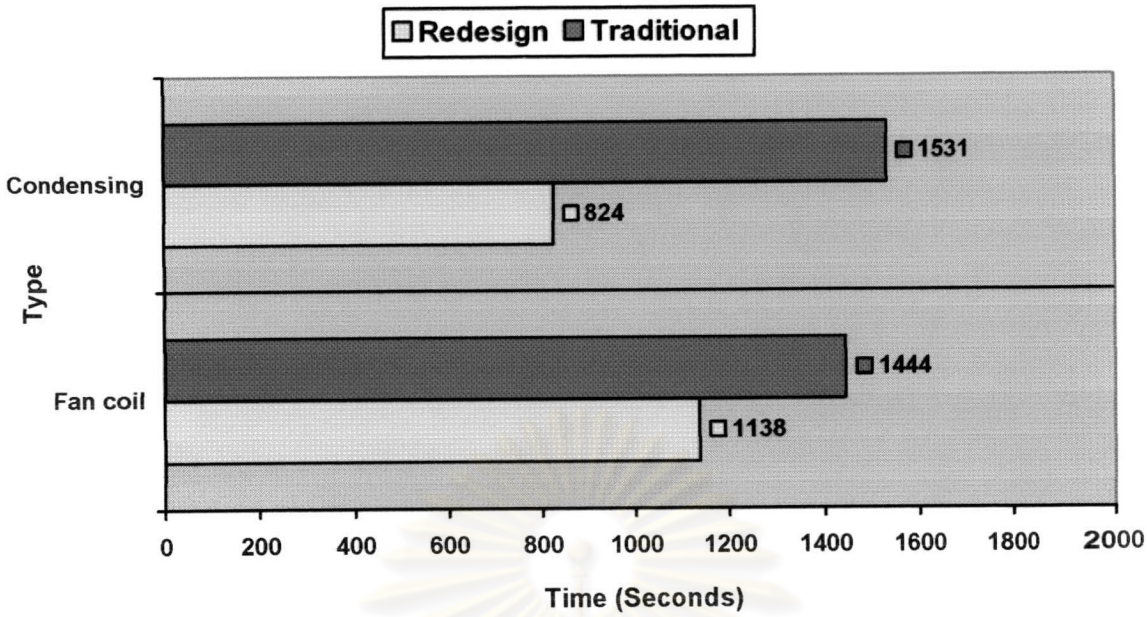

Figure 6-1b; Assembly time of traditional system and redesign system

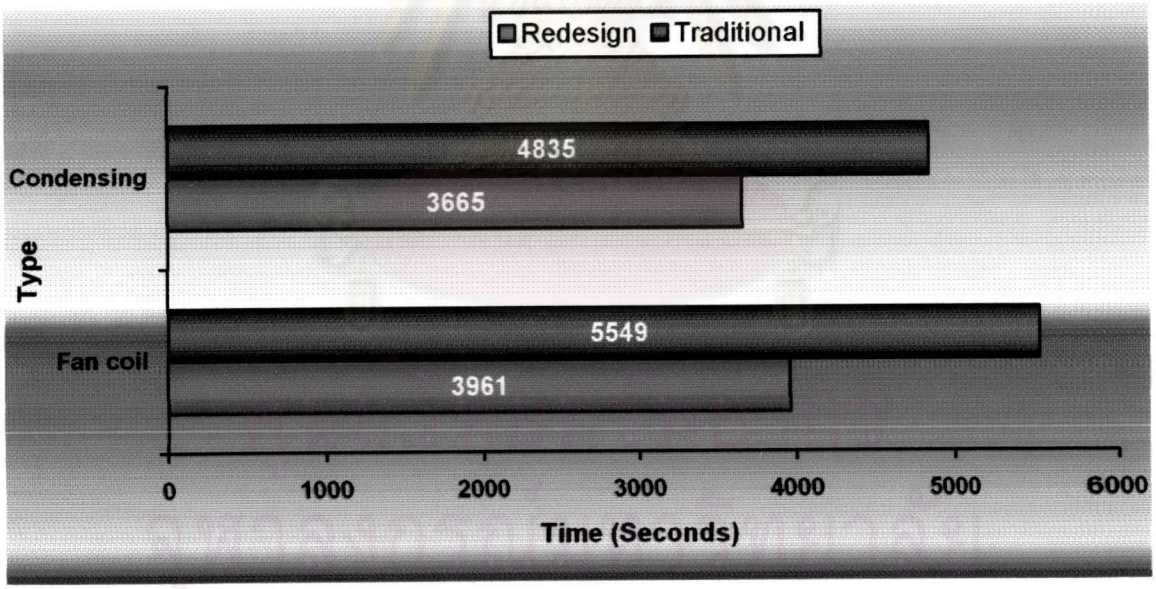

Figure 6-2; Summarization of process time in traditional and redesign system

1.2 Comments

An output of both system obviously stated that redesign system significantly shorten internal operation times within the workplace to almost half of the former system. The most substantial factor of reduction is from the direct methods improvement in chemical pools and painting stations. Cell design approach also provided continuous observation, particularly to the performances of team members in the cell. The standard operating procedure (SOP) sheet strictly controls operators to perform most efficiently. It is one way of motion study that seeks for best methods in practice. Moreover, to completely answer the question why former system use more time in assembly, the reply will be because the old station did not plan for line balancing like the redesign cells, in which tasks can be done on the same time.

Another point in fan coil process agility is that the new method chose to buy complete sets of complex components directly from advance providers. Avoiding assembling complexity can save time. For example, the factory buys cut-foam sheets directly from supplier instead of cutting it in shop floor. It saves about 950 seconds to the overall process time. The control sets and grille sets are also bought in complete sets for the same purposes.

Additional approach is at the arriving stock area where the conversion team assigned QC check spot to inspect every receiving part near the entrance. This spot might increase overall process time for about 600 – 700 seconds but it ensure values to the goods after the inspection rather than leaving items waiting idle for many hours at the raw material stock. It suits the phrase 'making it right at the first time' to pay more attention in quality subject.

Furthermore, separation of new work cells into sub-assembly and final assembly cells help to distribute complexity and burden from one independent station alone. The former system seems to have plenty of tasks in the final assembly stage because even motor set assembly, grille set assembly, air channel assembly, etc are all made at the final line. So after moving minor tasks away to other sub cells, it saves lots of time to the whole process flow. The changes reflect many things:

- The resolve of some personnel problems like bad posture or rush works
- The working methods have improve potentially
- The cell design based on practical procedures reduces congestion and create smoother flow of works internally
- The cell design methods has efficient control over worker's performance

2. Value-Added Improvements

2.1 Comparative Results

The terms of ensuring cellular manufacturing effectiveness after implementations can be crucially indicated by an output of non-value added activities ratio. That means the overall transportation and waiting time within the factory should be the crucial points of reducing.

Table 6-2 observed new flow of material and work since receiving to finished goods. The team finally recorded the transportation, waiting, receiving time again in case of drawing a complete diagram. The table has two sections; the non value-added time inside and outside the cell.

Non value adding time in the cell refers to time which waste during in activities of each cell about transmitting materials or unloading parts from stocks to do manual works. It consists of total unload time plus total transportation time in each cell. Therefore, outer transmission along the factory ground (not in workstation) or waiting time in raw material or finished goods stocks (not include WIP stock) will refer to time outside the cell.

Table 6-2a; Non-value added time sheet for new fan coil unit production

Fan coil unit (for production sets)		
List	**Non-value added operations**	**Time (seconds)**
Inside the cells		Transport + Unload
1	Chemical pool cell (A1)	52 + 60 = 112
2	Painting cell (A2)	81
3	Foam attachment cell (B1)	113 + 106 = 219
4	Back panel cell (B2)	23 + 15 = 38
5	Right-left panel cell (B3)	16 + 13 = 29
6	Cooling coil cell (B4)	43 + 23 = 66
7	Motor set cell (B5)	26 + 18 = 44
8	Top beam cell (B6)	5 + 14 = 19
9	Return grille cell (B7)	46 + 18 = 64
10	Assembly cell 1 (B8)	60 + 121 = 181
11	Assembly cell 1 (B9)	46 + 113 = 159
12	Assembly cell 1 (B10)	50 + 192 = 242
13	Assembly cell 1 (B11)	92 + 121 = 213
14	Test and pack cell (B12)	18 + 19 = 37
	Total	**1,504**

Outside the cells		
1	Receiving	1,800
2	Waiting (in RW and WIP stocks on shop floor)	3,600 + 480 = 4,080
3	Transporting or transmitting	780
4	Storing and unloading	840
5	Setting up	390
	Total	**7,890**

Table 6-2b; Non-value added time sheet for new condensing unit production

Condensing unit (for production sets)		
List	**Non-value added operations**	**Time (seconds)**
Inside the cells		Transport + Unload
1	Chemical pool cell (A1)	70 + 77 = 147
2	Painting cell (A2)	101
3	Bottom panel cell (C1)	31 + 11 = 42
4	Pipe Bending cell (C2)	18 + 8 = 26
5	Fan set cell (C3)	63 + 33 = 96
6	Control device cell (C4)	105 + 8 = 113
7	Foam attachment cell (C5)	29 + 21 = 50
8	Assembly cell 1 (C6)	101 + 129 = 230
9	Assembly cell 2 (C7)	158 + 172 = 330
10	Test and pack (C8)	18 + 19 = 37
	Total	**1,172**
Outside the cells		
1	Receiving	1,650
2	Waiting (in RW and WIP stocks on shop floor)	3,600 + 480 = 4,080
3	Transporting or transmitting	840
4	Storing and unloading	690
5	Setting up	390
	Total	**7,650**

From the given table, the team analyzed the proportion of value-adding percentage comparison to the non value-adding tasks. The summarization time of all value-adding operations is 3,095 and 3,301 respectively.

So the percentage of fan coil value-adding time from total operation's time
= [3,961 / (1,504 + 7,890 + 3,961)] x 100 = 29.66 %

So the percentage of condensing value-adding time from total operation's time
= [3,665 / (1,172 + 7,650 + 3,665)] x 100 = 29.35 %

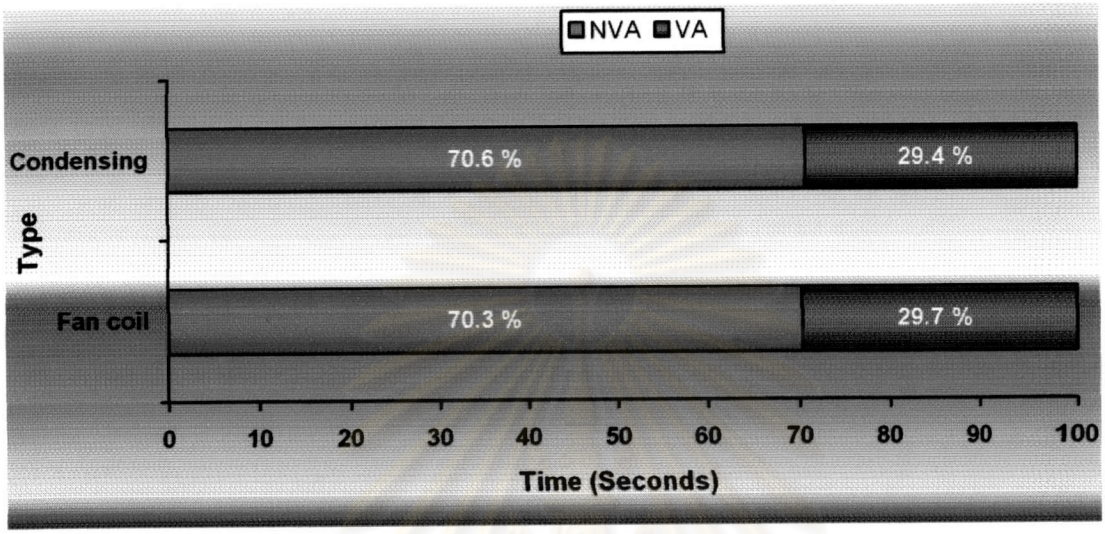

Figure 6-3; Value-added ratio of new processes redesign

2.2 Comments

There are obvious sign of improvements in the current ratio compare with previous ratios in figure 4-3 (chapter 4) which has the value-adding activities of only 11.3 % and 10.4 % respectively. The redesigned processes system focus apparently in two subjects; rearranging factory layout and cutting off the waiting and transportation time of materials and WIPs. In associate to the pull system, work pieces or parts do not have to wait for a long time before usage.

The conversion team adjusted layout in relative to movement of work flow together with loads and distances analysis. As illustrated in figure 5-25, there are no correlate cells that departed for more than 30 seconds of walking distant. That is why both values tend to move closer together. The fan coil value operations increases to 29.7 % while the condensing increase to 29.4 %. In both units, receiving time on the dispatching area tend to increase because QC staffs have been assign to strictly check every incoming goods for acceptable standard and reject them before entering any production stage. So it is worth for causing few more minutes instead of facing bottle necks later in the system if defects occur. The input goods are check at the arriving stock spot, just as explained in recent topic.

The storing and unloading time also decrease too. This happens because items are bought in smaller lot sizes, not above 200 units per item, but done with higher frequencies. The procedures of storing or unloading items from shelves, even WIP transmission between cells will be easy as a consequence. Cluttering and messy workplace problems are resolved. The changes in value-added ratio reflect many things:

- It clarifies better working environment and safety precautions
- It reduces confusion, surplus, and unnecessary range of work flow
- It simplifies that overall operations in the factory actually improve
- It affirms that redesign layout of the factory actually improve
- It reflects that even operators work with the same given period but their performance create more value to the products
- It reflects trends of continuous improvements into the future

3. Throughput Time Reduction

3.1 Comparative Results

Throughput time is the time that considers queuing time into an account, not only the overall operation time. It is the time of the whole system where a unit of product is made.

Traditional system

To derive the throughput time of the traditional system, the team followed the journey of a product's work piece and then perceives theoretically that it consists of different time which are processed time plus assembly time plus packing time plus WIP waiting time and plus transportation time. The results will be:

Throughput time of fan coil unit = 4,105 (- 950) + 1,444 + 120 + 5,756 + 900
= 11,375 sec ≈ 190 min

Whereas

4,105 is the total operation time on processing stations of tracked work piece
950 is the time use to cut foam insulator which is done during work piece is still in processing stage
1,444 is the total operation assembly time of tracked work piece
120 is the packing time of tracked work piece
5,756 is the waiting time of the work piece (WIP) until the whole lot (22 units) are finished in processing, assembling, transporting all together before carrying on with the next stage
900 is the transportation time of a tracked work piece

Throughput time of condensing unit = 3,304 + 1,531 + 120 + 3,270 + 750
= 8,975 sec ≈ 150 min

Whereas

3,304 is the total operation time on processing stations of tracked work piece
1,531 is the total operation assembly time of tracked work piece
120 is the packing time of tracked work piece
3,270 is the waiting time of the work piece (WIP) until the whole lot (22 units) are finished in processing, assembling, transporting all together before carrying on with the next stage
750 is the transportation time of a tracked work piece

Redesign system

Deriving the throughput time of the new system must summarize the operation time of all cells, therefore, recognizing the parallel activities in every cell. Because sub-assembly cells all operated at the same time, so only cell that has longest lead-time will be taken into account. For example, we will not add cell B3 and B4 operation time because it work on the same moment as cell B2 which spend higher time. Like cells B5 and B7 that work simultaneously with cell B6 but have lesser operating time. The situation will be simulated for peak summer demand.

Throughput time of fan coil unit = 2,823 (- 90) + 90 + 73 + 135 + 89 + 176 + 102 + 84 + 219 + 3,900 = 7,601 sec = 126.7 min

Whereas

2,823 is the total operation time on processing stations of tracked work piece
90 is the operation time per unit of B1 cell
73 is the operation time per unit of B2 cell
135 is the operation time per unit of B6 cell
89 is the operation time per unit of B8 cell
176 is the operation time per unit of B9 cell
102 is the operation time per unit of B10 cell
84 is the operation time per unit of B11 cell
219 is the operation time per unit of B12 cell
3,900 is an accumulate waiting time of the whole lot (12 units) in every cell to finish processing, sub-assembling, final assembling, testing, packing, and transporting all together

Throughput time of condensing unit = 2,841 + 152 + 94 + 188 + 96 + 219 + 3,480 = 7,070 sec = 117.8 min

Whereas
2,841 is the total operation time on processing stations of tracked work piece
152 is the operation time per unit of C2 cell
94 is the operation time per unit of C5 cell
188 is the operation time per unit of C6 cell
96 is the operation time per unit of C7 cell
219 is the operation time per unit of C8 cell
3,480 is the accumulate waiting time of the whole lot (12 units) in every cell to finish processing, sub-assembling, final assembling, testing, packing, and transporting all together

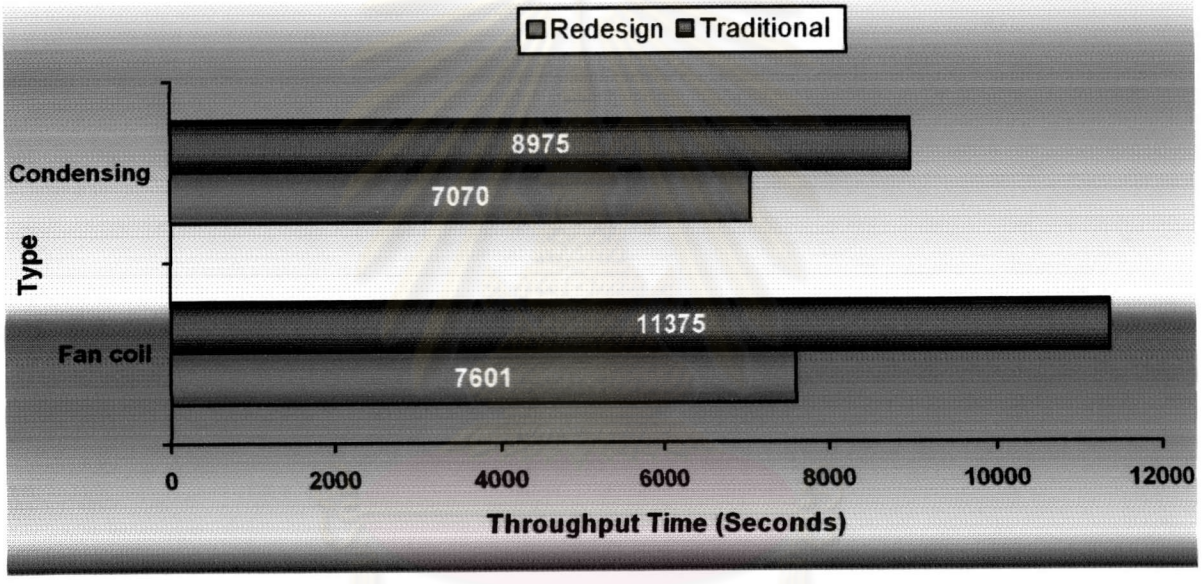

Figure 6-4; Throughput time in traditional and redesign system

4. Any Quality Improvements?

4.1 Comparative Results

Quality improvement is an optional benefit. Since new implementations, the factory decided to setup quality control at every operation stage. All cells have QC inspection to reduce defects and reworks, changing from previous quality system which randomly checks only few items in the lot. The main target of cellular quality assurance is having zero defects and errors, or at least pressing it lower than 0.5% before selling to customers. Table 6-3 depicts the history of defects and reworks causes by suppliers and workers during the year 2003.

Table 6-3; Defects and errors record from year 2002 to 2003

Date / Detail	2002						2003						
	Traditional Quality Control						Redesign Quality Control						
	16 – 31 Aug	1 – 15 Sep	16 – 31 Sep	1 – 15 Oct	16 – 30 Oct		16 – 31 Dec	1 – 15 Jan	16 – 30 Jan	1 – 15 Feb	16 – 28 Feb	1 – 15 Mar	16 – 23 Mar
Defects in workstation cause by suppliers	0.64 %	0.68 %	0.52 %	0.55 %	0.49 %		0.22 %	0.16 %	0.15 %	0.16 %	0.13 %	0.13 %	0.20 %
Average 1	0.58 %						0.16 %						
Errors and reworks in the workstation cause by operator's fault	0.56 %	0.53 %	0.35 %	0.32 %	0.30 %		0.03 %	-	-	0.01%	-	-	0.02 %
Average 2	0.41 %						0.009 %						
Total	1.2 %	1.21 %	0.87 %	0.87 %	0.79 %		0.25 %	0.16 %	0.15 %	0.17 %	0.13 %	0.13 %	0.22 %
Average 3	0.99 %						0.17 %						

Close for factory rearrangement and preparing (45 days)

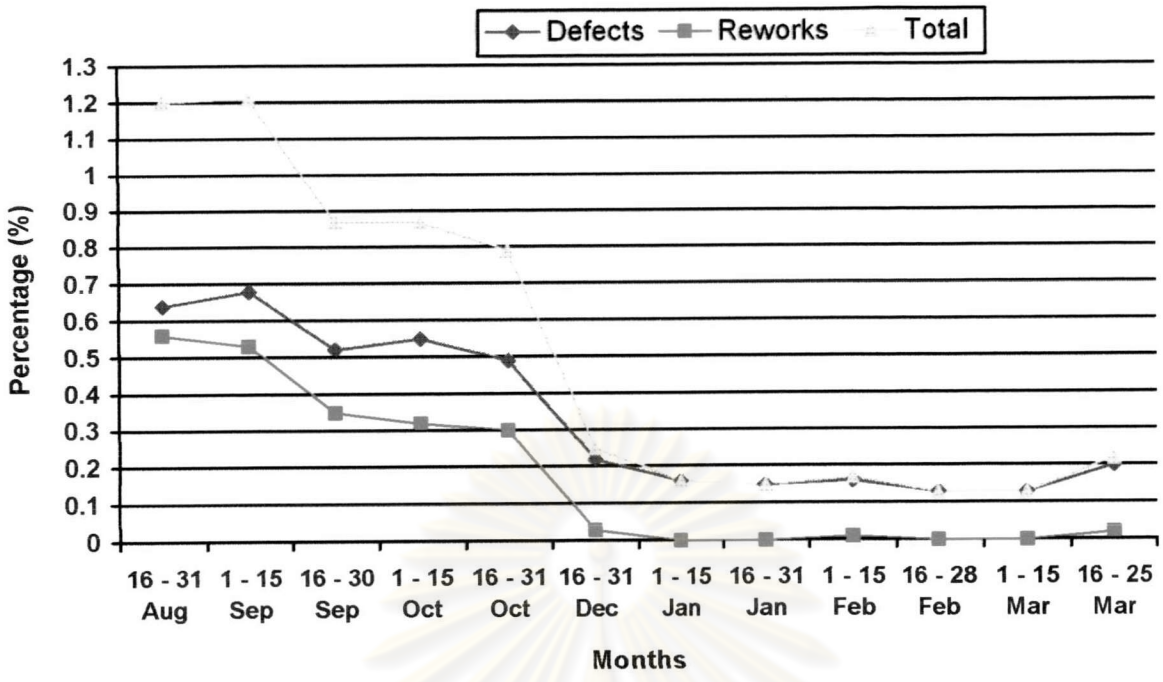

Figure 6-5; History of quality improvements in the factory

4.2 Comments

Figure 6-5 shown that since redesign implementations concerning with quality aspects are approved with cell design, the rate of defects caused by suppliers and errors from workers in releasing unqualified work pieces through workstations has been surprisingly reduced. This is no questioning because there are non quality incentives in previous manufacturing system. That is why it is a one-way improvement when implementing any techniques.

The QC inspection point successfully checks incoming part's specifications for breakdown, worn out, deep scratch, deformation, and other mismatch orders. They reject under standard parts back to the suppliers before assembly otherwise they will face failure situations at the final testing station like in pass days. The operators learn the lesson in how troublesome it will make to have defects at finished good's stage. So they carefully watch over the whole system to push defects nearest to zero. Their feelings are to make it right at the first time rather than having headaches ahead.

As the matter of fact, to ensure every attribute and function of components to work properly, it can not be done by external inspection. So there are still some internal defects which workers encounter in functional and voltage testing stage. The chance of encountering is only about 0.16 %.

The errors occur by worker's fault also reduce down to almost 0 % from the previous system because of the QC member in every cell. Workers often create mistake after handling long period of final assembly operations. The cellular system encourages team members in each cell to discuss before working and share work responsibility to everyone in the cell appropriately. Planned SOP helps members to follow the operation instruction steps quite easily as well.
The improvements in quality reflect many things:

- It shows that the QC inspection stage in every cell work effectively
- It consequently reduces occurrence of bottle necks (if there are less defects or reworks, workers will not have to waste time removing it and the system can continue smoothly)
- It eliminates delays from defects or reworks
- It consequently reduces safety inventory storage
- It enable more spaces and congestion in the factory

5. Recommendations and Suggestions

Rearranging the shop floor layout into a manufacturing cell is not really an end point to the redesign implementations. It is actually the starting position of continuous improvement of the process. Although the new processes dramatically shortens lead-time and increase value-adding activities percentage as shown above, it still has some critical success factors to develop further and built cellular behaviors into the factory culture. Here are more suggestions and recommendations to S-Pak factory in order to maintain the competitive advantage successfully.

Shorten cycle times for each cell

The operations in every cell still need more arrangement to balance cycle time in each cell not to differentiate too much. When earlier operations in preceding cells have shorter cycle times, the WIP they produce will be left uselessly in the Kanban containers for a period of time. This make some cell's resource sitting idle. Conversely, if the early cell has longer cycles, the next cell will be left waiting for request Kanbans.

Furthermore, it is important to look for creative ways to shorten the production processing time by testing with real performance of the operators in the teams and letting them suggest for their best way of work. The team reviews the steps of the operations to see where time could be cut or balance with other activities. For example, if the production time per one work piece nearly reach the limit takt time, the manager might revise by preparing more safety stock, approach better forecasting techniques, or hire more workers in that cell. Eventually, the bottle neck will finally be resolved.

Personnel issues

Employees in cellular system are very important factors for success. All people have their role connect to the whole system as small elements. If worker themselves can realize their benefits, it is like opening the gate to success. Here are some issues which employees must understand:

- Members in the team must believe that the new system will really benefit the company and it is better than the traditional system in both organizational aspect and personal aspect.

- Members might sometimes find the job more complex. It is the manager and supervisors duty to always inform that they are not forced to work harder, but because the system have reduce all wasteful non value-adding activities such as walking, stocking, or transmitting so they have valuable time to put more effort (value) in the same amount of time require. So with the new system, workers will have more break times or can go home faster than usual.

- Members are influence to work as a team. The new processes will establish team working culture into the company culture and members should be informed to realize the advantages than doing things alone.

  With the weekly task position switching of the workers, the old worker will train and teach techniques to the new workers in discussion period or at the end of the week.

- Now members have more freedom to choose styles of performance in whether they want without having supervisors pointing finger commanding them what they should do. The workers empower themselves in their assigned task. All responsibilities are shares by members in the team afterwards.

Other management issues

After changing to new processes, the following data, documents, and manual sheets must be updated immediately by not interrupting the work. The management concepts need to be flexibility to respond quickly in changing trends, fluctuate demands, or market requirements.

Because the company sells seasonal products, when it comes to lower order or low season (9 months) period, which is a long time, the factory must set a new plan to make workers work in few days, pay by working hours, or receive minimum wage. This helps in cost reduction instead of making workers (labors) working full time from Monday to Saturday.

6. Conclusion

To redesign the processes of the factory, there are many things to consider. First is what the core improvements will be. Second is understanding the current conditions of the factory and characteristic of our products. To analyze the situations correctly, there are systematic tools and techniques available to apply. The environments must be identified to the root of the problems to see areas of further improvements. Finally are the redesign implementations.

It is proven that an Spilt-type air condition assembling factory which have a medium-scale, produce in moderate variety, making to order environment is suitable for cellular manufacturing and pull system. Cellular manufacturing is more than a series of techniques. It is a fundamental approach to improving the manufacturing process by covering many aspects together to matter it is a quality aspect, time aspect, or even design aspect.

Problems might occur during the changes. Some of them, the team did not prepared to encounter. What is troubling the team most is the worker resistance to change from what they are use to do on daily routine. However, after setting up the seminar to inform workers while the factory is shut down to arrange layout, installing new machines, and building internal cells, workers have opportunity to revolute their thinking. The outcome turns out that it is not too hard to develop ways of work when workers accept that they receive higher benefits from traditional system and with enough time to practice in slow season.