CHAPTER V

Result, Conclusions and Suggestions

5.1 Results

The Cellular Manufacturing has been implemented at the normal output rate. The improvement can be considered in terms of the line characteristics and the actual line performance.

5.1.1 Line Design improvement

Table 5.1 : Conveyor Line Characteristics

Conveyor Line						
Process	Capacity	Manpower	SST	OP	WIP	Area (m^2)
Hand-Mount	500	9	7.293	79.44%	17	19.04
Dip Machine	500	0	0	0	7	2.4
Touch-Up	500	3	2.625	85.78%	5	4.2
ICT	500	2	0.75	36.76%	4	6.0
CBA	500	2	1.25	61.27%	5	
Final Inspection	500	1	0.767	75.20%	5	0.3
Packing	500	1	0.523	51.27%	2	0.3
Total	500	18	13.208	72%	45	32.24

The conveyor line is designed to have the characteristic as shown in the table 5.1. This is the basic of the conveyor line operation.

The cell line characteristic is shown in the table 5.2 with the same format of the conveyor line for comparison.

Table 5.2 : Cell Line Characteristics

Cell Line						
Process	Capacity	Manpower	SST	OP	WIP	Area (m^2)
Hand-Mount	500	8	7.293	89.38%	8	16.8
Dip Machine	500	0	0	0.00	7	2.4
Touch-Up	500	2	2.625	128.68%	3	1.0
ICT	500	3	2	65.36%	2	0.40
CBA					3	2.66
Final Inspection	500	1	0.767	75.20%	2	0.3
Packing	500	1	0.523	51.27%	2	0.3
Total	500	15	13.208	86%	27	23.86

The improvement ratio can be shown in the table 5.3 based on its design

Table 5.3 : Improvement Ratio

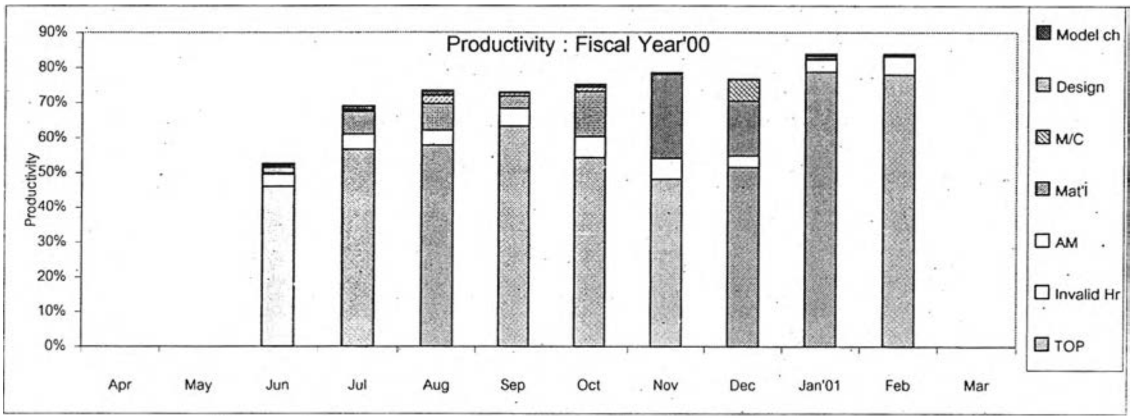
Parameters	Conveyor Line	Cell Line	Improvement
Manpower (persons)	18	15	16%
Operational Productivity (%)	72	86	14%
Work-In-Process (board)	45	27	40%
Area (m^2)	32	24	26%

5.1.2 Actual performance improvement result

5.1.2.1 Productivity index

The new cell line has been implemented in January 2001. The Productivity Index has shown the significant improvement in comparison to the conventional production style.

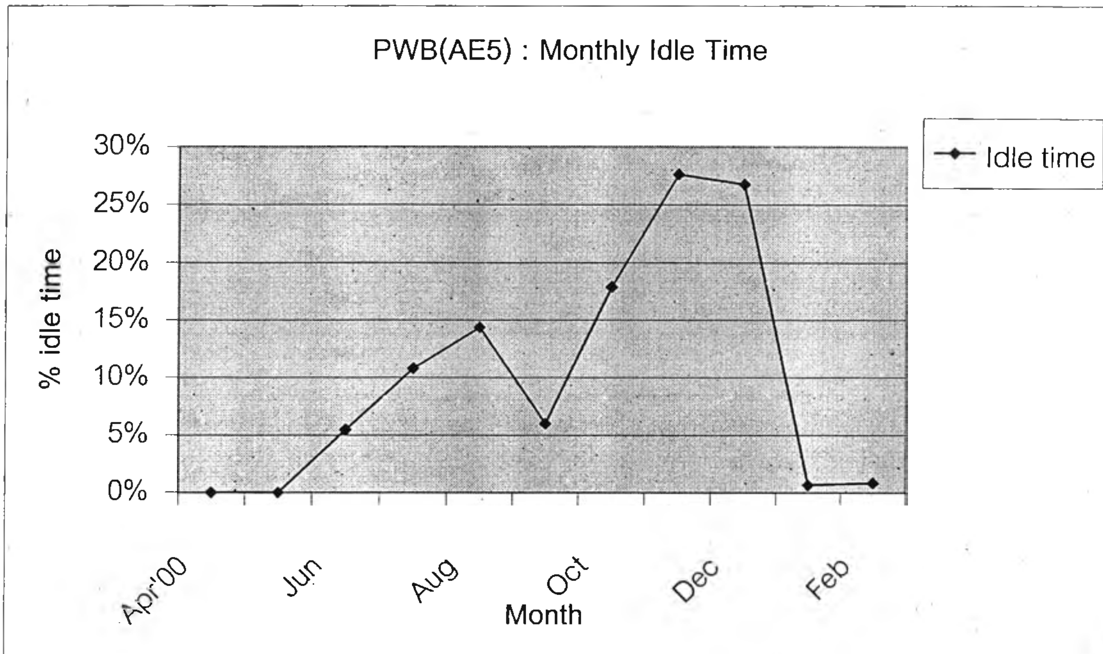
Anyway, the operators who worked in the cell line have undergone training on the new mounting method for a month before actual implementation and all are the experienced operators in the conveyor line before.



Productivity	Apr'00	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'01	Feb	Mar
OE	N/A	N/A	52.59%	69.08%	73.48%	73.00%	75.18%	78.53%	76.68%	83.83%	83.90%	N/A
OP	N/A	N/A	49.51%	61.03%	62.12%	68.29%	60.25%	54.09%	54.82%	82.27%	83.14%	N/A
TOP	N/A	N/A	46.00%	56.57%	57.79%	63.31%	54.22%	48.06%	51.48%	78.69%	77.95%	N/A
Invalid Hr	N/A	N/A	3.51%	4.46%	4.33%	4.97%	6.03%	6.03%	3.34%	3.58%	5.19%	N/A
AM	N/A	N/A	0.26%	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	N/A
Mat'l	N/A	N/A	1.76%	6.36%	7.53%	3.61%	12.84%	23.94%	15.69%	0.27%	0.27%	N/A
M/C	N/A	N/A	0.56%	0.53%	2.30%	0.78%	1.34%	0.10%	6.00%	0.72%	0.49%	N/A
Design	N/A	N/A	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	N/A
Model change	N/A	N/A	0.51%	1.12%	1.52%	0.31%	0.70%	0.39%	0.17%	0.57%	0.00%	N/A
Output per day	N/A	N/A	1800	1800	1540	800	1420	480	380	530	160	N/A

Figure 5.1 : Monthly Productivity

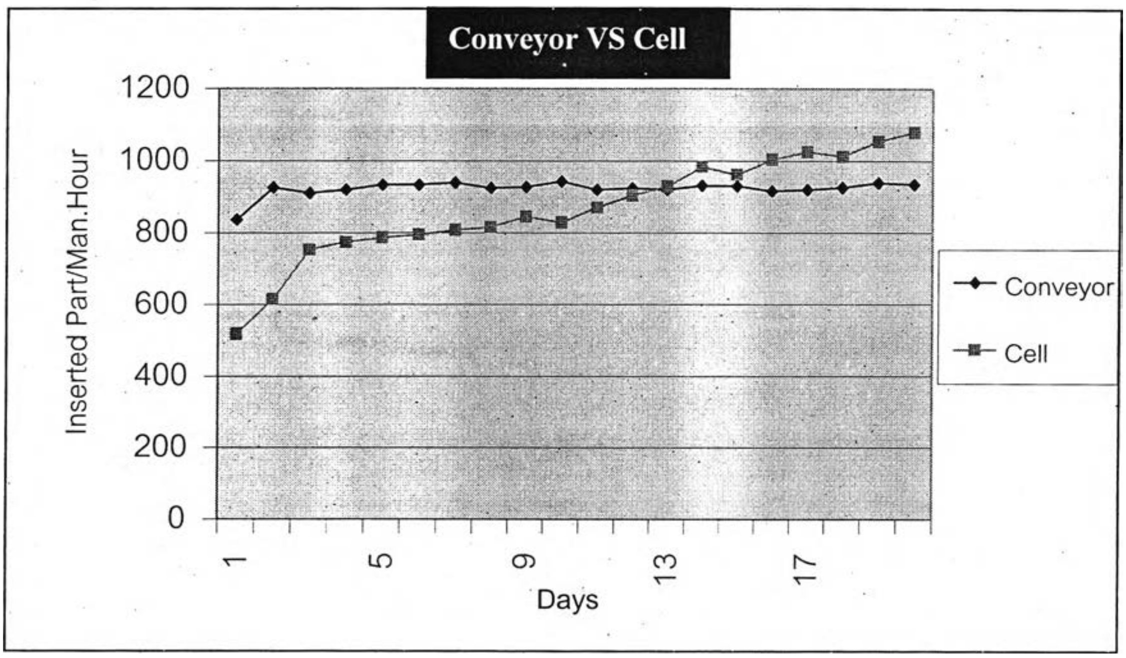
The result has shown a drastically improvement. The Operational Productivity is improved from 50-60% to 80 % up but this is maybe the less impact of material shortage problem. The work hour of productivity data is shown in the appendix 5.1. The breakdown idle time is shown in the appendix 5.2. The graph of figure 5.2 shows the idle time improvement tendency in terms of the proportional to the total available hours.



Month	Apr'00	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'01	Feb
AM	N/A	N/A	51.6	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0
Mat'l	N/A	N/A	340.5	979.7	1095.3	429.2	936.9	1097.0	468.0	11.3	2.3
M/C	N/A	N/A	103.8	72.9	288.7	87.5	79.1	3.3	128.3	29.5	4.0
Design	N/A	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Model change	N/A	N/A	92.5	151.3	181.2	34.3	40.3	12.4	3.3	23.2	0.0
Other	N/A	N/A	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total idle time (hr	N/A	N/A	588.4	1209.2	1565.2	551.0	1060.6	1112.7	599.7	64.0	6.3
SST	N/A	N/A	4968.4	6339.2	6290.9	5832.4	3218.2	1934.0	1153.2	2821.0	572.4
Invalid Hr	N/A	N/A	766.0	819.6	759.5	671.1	594.1	448.9	136.4	57.6	45.8
Total available hr.	N/A	N/A	10801.0	11205.8	10886.5	9212.0	5935.3	4024.5	2240.0	3585.0	734.3
Output/day	N/A	N/A	1800	1800	1540	800	1420	480	380	530	160
% Idle time to total available hr.			5.45%	10.79%	14.38%	5.98%	17.87%	27.65%	26.77%	1.79%	0.85%

Figure 5.2 : Monthly Idle Time

In order to benchmark between the conveyor line and the cell line, the Hand-Mount process is studied by use of the average inserted part/operator-hour to confirm the actual effectiveness. The learning curve is approximately 13 days to catch up the speed of the conveyor belt and the tendency is going up in the figure 5.2. The data has been collected from the cell operation in Jan 2001 and compared with the historical data of the hand mount process of the conveyor belt.



Date		Part/Head-Hour																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PCDAE$_5$	Conveyor	836	926	911	920	933	933	939	924	927	942	920	924	920	931	929	916	920	926	939	935
	Output	450	498	490	495	502	502	505	497	499	507	495	497	495	501	500	493	495	498	505	503
PCDAE$_5$	Cell	519	615	753	774	786	795	807	815	845	828	870	903	928	983	962	1004	1025	1012	1054	1079
	Output	124	147	180	185	188	190	193	195	202	198	208	216	222	235	230	240	245	242	252	258

Note :

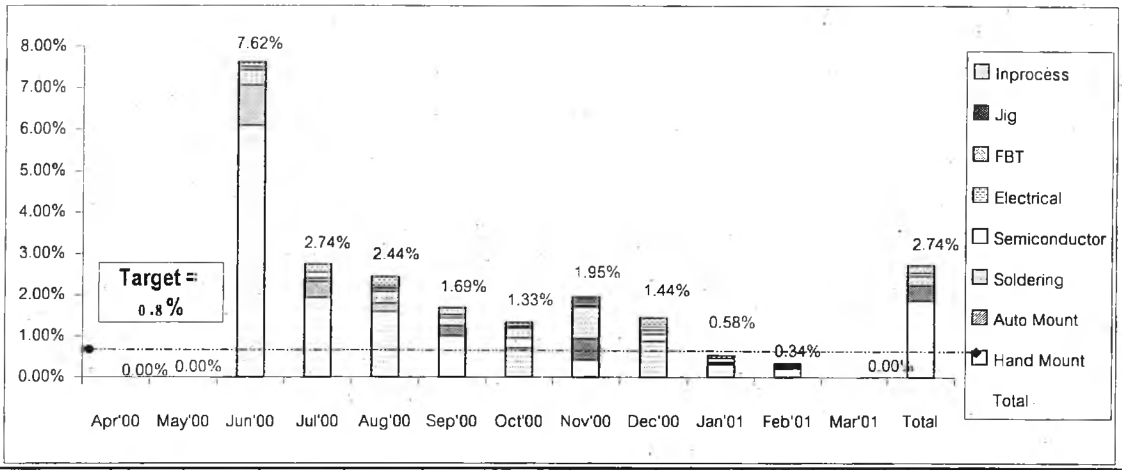
Part quantity= 138 parts per board

Manpower= 9 operators for the conveyor belt and 4 operators for a cell

Figure 5.3 : Inserted Part/Man.Hour

5.1.2.2 Quality index

PWB (AE-5) : MONTHLY ICT DEFECT RATIO

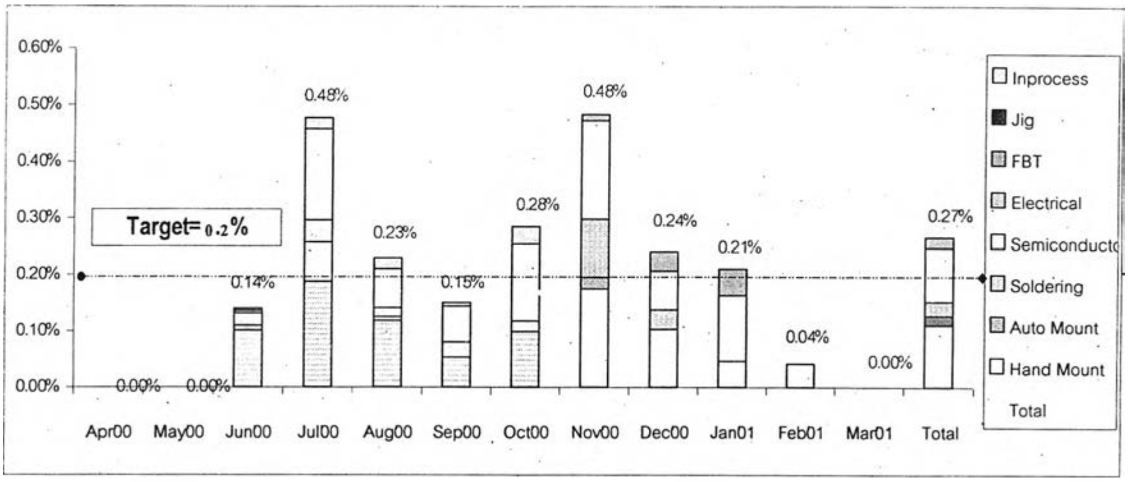


Week	Apr'00		May'00		Jun'00		Jul'00		Aug'00		Sep'00		Oct'00		Nov'00		Dec'00		Jan'01		Feb'01		Mar'01		Total	
OUTPUT	0		0		22832		30403		30464		29936		16145		9735		5816		12864		2373		0		160568	
DEFECT	0		0		1739		834		744		505		214		190		84		74		8		0		4392	
% DEFECT	0.00%		0.00%		7.62%		2.74%		2.44%		1.69%		1.33%		1.95%		1.44%		0.58%		0.34%		N/A		2.74%	
CAUSE/RESP	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def
Hand Mount	0.0	0.0	0.0	0.0	1390	0.06	589	0.02	485	0.02	299	0.01	114	0.0	41.0	0.0	51	0.01	40	0.00	5	0.00	0	N/A	3014	0
Auto Mount	0.0	0.0	0.0	0.0	223	0.01	118	0.00	62	0.00	76	0.00	41	0.0	51.0	0.0	10	0.00	3	0.00	1	0.00	0	N/A	585	0
Soldering	0.0	0.0	0.0	0.0	84	0.00	24	0.00	88	0.00	59	0.00	38	0.0	75.0	0.0	6	0.00	4	0.00	0	0.00	0	N/A	378	0
Semiconductor	0.0	0.0	0.0	0.0	17	0.00	45	0.00	21	0.00	20	0.00	8	0.0	3.0	0.0	5	0.00	12	0.00	1	0.00	0	N/A	132	0
Electrical	0.0	0.0	0.0	0.0	25	0.00	58	0.00	87	0.00	50	0.00	13	0.0	20.0	0.0	12	0.00	9	0.00	1	0.00	0	N/A	275	0
Tuner	0.0	0.0	0.0	0.0	0	0.00	0	0.00	.0	0.00	0	0.00	0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	N/A	0	0
Touch-up	0.0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.0	0.0	0.0	0	0.00	6	0.00	0	0.00	0	N/A	6	0
FBT	0.0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	N/A	0	0
Jig	0.0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	N/A	0	0
Inprocess	0.0	0.0	0.0	0.0	0	0.00	0	0.00	1	0.00	1	0.00	0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	N/A	2	0
Re adj. OK	0.0	0.0	0.0	0.0	0	0.00	0	0.00	0	0.00	0	0.00	1	0.0	3.0	0.0	4	0.00	9	0.00	0	0.00	0	N/A	17	0

Figure 5.4 : Monthly ICT Defect

The data has shown significant improvement in ICT defect, especially the hand mount defect. The fast action can help stop any continuous defects or epidemic defects. The less work-in-process & visualized status of production can support the production control and management to be more effectively.

PWB(AE-5) : MONTHLY CBA DEFECT RATIO



Week	Apr00		May00		Jun00		Jul00		Aug00		Sep00		Oct00		Nov00		Dec00		Jan01		Feb01		Mar01		Total	
OUTPUT	0		0		22832		30403		30464		29936		16145		9735		5816		12864		2373		0		160568	
DEFECT	0		0		32		145		70		45		46		47		14		27		1		0		427	
%DEFECT	0.00%		0.00%		0.14%		0.48%		0.23%		0.15%		0.28%		0.48%		0.24%		0.21%		0.04%		N/A		0.27%	
CAUSE/RESP	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%Def	Q'ty	%De	Q'ty	%Def
Hand Mount	0	0.00%	0	0.00%	23	0.10%	57	0.19%	36	0.12%	16	0.05%	16	0.10%	17	0.17%	6	0.10%	6	0.05%	0	0.00%	0	N/A	177	0.11%
Auto Mount	0	0.00%	0	0.00%	2	0.01%	21	0.07%	2	0.01%	0	0.00%	0	0.00%	2	0.02%	0	0.00%	0	0.00%	0	0.00%	0	N/A	27	0.02%
Soldering	0	0.00%	0	0.00%	0	0.00%	12	0.04%	5	0.02%	8	0.03%	3	0.02%	10	0.10%	2	0.03%	0	0.00%	0	0.00%	0	N/A	40	0.02%
Semiconductor	0	0.00%	0	0.00%	5	0.02%	49	0.16%	21	0.07%	19	0.06%	22	0.14%	17	0.17%	4	0.07%	15	0.12%	1	0.04%	0	N/A	153	0.10%
Electrical	0	0.00%	0	0.00%	1	0.00%	6	0.02%	6	0.02%	2	0.01%	5	0.03%	1	0.01%	2	0.03%	6	0.05%	0	0.00%	0	N/A	29	0.02%
Tuner	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	N/A	0	0.00%
Touchup	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	N/A	0	0.00%
FBT	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	N/A	0	0.00%
Jig	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	N/A	0	0.00%
Inprocess	0	0.00%	0	0.00%	1	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	N/A	1	0.00%
Re adj OK	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.02%	1	0.04%	0	N/A	4	0.00%

Figure 5.5 : Monthly CBA Defect

The CBA did not show much improvement in Jan because the major defect was the semiconductor defect that was related to the part quality. Anyway, the hand mount defect showed zero defect in February when the operators have got better skill. In addition, the quality issue of the part in January was resolved so the defect of February is the lowest in the year.

5.2 Discussion

The concerned point of the cell line is the qualification of operators. The multi-skill operators are needed to work in the cell at the front end because the one man operation is essential when the out put rate is so small. The back end of the production line also requires an operator who is able to work more than one job such as the inspection and packing. As a result, the learning curve of the cell line is longer than the conveyor belt line. The conveyor line is effective with the batch production and consistency of the order and the inserted parts per operator are much less than the cell line. The learning curve is fast and it is easy for training. Unfortunately, the fact is that the firmed order does not exist in the current business atmosphere any longer. This makes the cellular manufacturing really powerful methodology in present business condition.

5.3 Conclusions

The improvement of productivity can be achieved by application of the group technology concept to eliminate the conveyor belt out of the production line that has weak points in terms of flexibility, hidden wastes, ownership etc. Cells are introduced to the production line to complete the product within the individual cell and this is so called "Cellular Manufacturing". Unfortunately, the whole production line of PWBA cannot be arranged to fit within one cell because there are several constraints i.e. dip machine size, space limit, more equipment investment. The cell is developed into the production line as the process cell and causes 4 key changes as follows :

1.Hand mount : The "loop cell" is designed and operators mount the parts on the manual cart instead of mounting on the conveyor line. The conveyor belt function is just to carry the board into the dip machine only, not controlling the output rate of the process. This allows the process to have self-continuous improvement in their speed and high flexibility in operation management causing waste reduction, various output rate, quality improvement. The major contribution to this success are; (1) ownership : operators get involved with their job result directly. The more cooperation they do, the more output they get. This can build up the self-continuous improvement value among themselves. It encourages operators to work with their full potential, (2) manual Operation : this allows operation to be highly flexible. Once the part sequence is not fixed, there are many patterns of mounting that can be modified to match the production situation. The similar part cab be separated by changing the sequence causing the quality improvement. The jobs can be combined or divided among workstations depending on the manpower condition. With the loop layout, the information of the board quality can be flowed quickly due to face-to-face communication. One operator can walk around the loop and produce the board as one-man-operation that can vary the output rate. The autonomous line balance can be introduced by training multi-skill operators so that they can help each other within their group.

In addition, the time & motion study is carried out to change the mounting method to eliminate the eye catch time. The part box is designed to ease the grasp motion. There are additional improvement activities in supporting function to increase the productivity. The refill part system is established to eliminate the idle time of the direct operators. The lighting signal is installed between touch up process and hand mount process to serve the Just-in-Time concept.

2. Touch up : The conveyor belt is taken out and install the manual slide rail. Operators have to work in series so that they can speed up themselves. If not, the next operator is idle to wait for the board. There is no excess stock by turning on the signal light to stop the hand mount process.

3. ICT & CBA : The combination of these 2 processes help the reduction of waiting time waste and WIP.

4. Final inspection & packing : These 2 processes are re-layout to accommodate the cell concept that allows these processes to work as a group. The Work-In-process, the waste movement & space can be reduced.

The cellular manufacturing has been implemented since January 2001. The result of this research can concluded in response to the problems raised earlier in this thesis as follows :

1. Schedule change : The February production was just 160 boards per day whereas the January production required 530 boards per day. There are about 3 times reduction in the customer requirement but the productivity has shown no significant difference between January and February. In addition, there was no any re-layout or process change impact that the cost of this matter was saved. The production has been run by one man operation at hand mount process by 2.5 operators instead of full cell of 4 operators in January. The hand mount operator just walks around the loop with the manual cart. The touch up, ICT/CBA, final inspection and packing can use 2 operators to work and help each other according to the standard stock control between processes. In daily production, this concept can be also applied. For example, there was a material delay problem on Jan 16^{th} , so the production has run the board by one cell only during Jan 15^{th} and 16^{th}. As the data in the appendix 5.1 shows that the standard time of the boards were dropped from approximately 98 hours per day to 45.76 hours on Jan 15^{th} and 47.52 hours on 16^{th}. The half of operators was loaned to other production lines causing no impact to the productivity.

2. Quality : The ICT has been improved dramatically from 1.44% of ICT defect in Dec '2000 to 0.58% in Jan'2001 and 0.34% in Feb'2001. The real time actions are effective. The standard stock control makes the production line abnormal condition visualized because the bottleneck occurs in the process causing line stoppage due to exceeding standard stock control in between processes.

The CBA defect was still high at 0.21% in Jan'2001 but it was from the semiconductor part that was not related to the line performance. It has become 0.04% in Feb'2001.

3. High idle time : This idle time discussed here is from operators pushing the button

switch to stop the conveyor belt when an operator cannot complete the job within the cycle time at the hand mount process. This is totally eliminated by the cell line. The jobs can be shared according their skill without the need of re-layout or process changes.

4. Sluggish improvement : This is one of the strong points of the cellular manufacturing that the teamwork is built up and create the self-improvement value. The operators can produce the board at their full potential. The experienced operators in cell line can catch up the conveyor line output by 13 days approximately and exceed the performance of the conveyor line by 1079-935/935 (inserted part quantity per operator-hour) = 15.4% as shown in the figure 5.2. Furthermore, the ownership is enhanced because the output can be tracked back individually and

5. High inventory : The cells of hand mount and taking the conveyor out of the back end process can reduce the WIP (work in process). The stand stock control in between processes can be effectively implemented based on just in time concept through the standard stock control in between processes. The work in process is just obtained as necessary. The WIP in between processes is to absorb the variation of processes. There is one board in between processes of ICT , CBA, final inspection and packing. 40% of WIP can be reduced as shown in the table 5.3.

6. Changeover loss : This is still not fully implemented in the current production. This is related to the material availability. The part lead time is 2-3 months so it will be implemented by the 1st quarter of this fiscal year. There were 23.2 man-hours loss in model change in Jan'2001 and showed zero model change loss in Feb'2001 because the customer required just one model in this month. Based on the line design, the 2 models can be run in parallel, one model for each cell.

5.3 Recommendations

The Cellular Manufacturing has shown a significant improvement result in productivity. The ownership & flexibility is the major value to improve the waste time & selfdevelopment in processes. The operation has been changed to be more manual base control. There are several point that could be extended for study as follows:

1.The operation shall be further studied to determine the optimized condition. For example, the quantity of parts per operator shall be on what number that is most appropriate based on human capability.

2. The human resources are the key factor in the manual operation. To accelerate the learning curve shall have an effective Education/Training system. The cell operation requires multi- skill operators. There are several points to simplify the operation such as user-friendly work instructions, single step of thinking picture.

3. Heijunka Production is the Japanese production system to maintain the maximum of production capability by models allocation to avoid idleness and still support the market demand timely without overstock problem.