CHAPTER III

Manufacturing Process Analysis

3.1 Existing system

The process flow is shown in the figure 1.1 and the line layout of the conveyor belt is referred to the appendix 3.1. The detail of each process can be described as follows:

3.1.1 Hand mount

This is a standing work operation. The workstation is installed beside the conveyor belt. There is one shelf for each workstation that is operated by one operator. The shelf contains several part boxes. The quantity of workstation depends on PWBA model. More complicated board needs more workstations to fit all components onto the board.

The brief of this process can be explained as followings. The mounting method is to insert the component on the board during the running of conveyor belt so it is necessary to put the components started from the side that reaches the operator first and then continuing insertion to the other side. This is the limitation in part sequencing design. It affects to both quality and productivity. The good parts' sequencing can reduce the human error i.e. wrong inserted parts, bent leg etc. The fix sequencing also causes the fix of the line capacity that cannot be adjusted in real time and the loss of productivity occurs if the production demand is less than the capacity.

Basically, one operator mounts parts around 5-10 pieces. If the part quantity per operator is higher, the part boxes are increased and face the limit space over the conveyor belt. The speed shall be fast enough to maintain the appropriate quantity of parts per operator so it is the limitation of this process that is not good for the small lot production.

This is the 1st process of the production line so it determines if the daily output achievement is feasible. The studied model in this research is AE5 model of PWBA for Digital Television product in UK branch. The detail of process design is described as follows:

3.1.1.1 Process design (Conveyor Type)

1. Find the parts to be mounted by hand from Master BOM. In the Master BOM demonstrated below, all mounted parts on the board are listed. These are both mounted by hand and machine. The hand mount parts can be identified by US code and UDCP code. There are 2 conditions that these 2 codes identify the part as the hand mount part as follows :

1.1 The US code is shown as a Blank. It means the hand mount part.

1.2 If the US code is shown as "S", the 3rd digit of UDCP code must be shown as " - ". It means the hand mount part.

Hand mount parts are picked up from Sample of Master BOM in the table 3.1 to demonstrate how to identify the type of parts.

11 1-104-665-91 *B6193*	***M*** 1A-	*2 C6658,6659* *-P—C-*	*CAP, ELECT 100MF* *AA751251*
11 1-107-368-51 *C5759*	 -1--	*2 C6810,6811* *P--C-*	*CAP, PETP FILM 0.047MF* *AA751251*
10 1-107-565-11 *02 GC D6717*	***S*** -1--	*1 C6607* *P--C-*	*CAP, FILM 0.33MF* *AA751251*

In column 2 ; *US Code is Italic letter of the row 1*

; UDCP is the regular letter of the row 2.

Table 3.1 : Sample of Master BOM

```
P/N  (MPF105)      P: 002       ** PCL RETRIEVAL  **          D325 01.02.19
19:20
--------------------------------------------------------------------------------------------------------
---------------
   Parent-No.    UDCP     Description                      Original Model
   A1640395A      -1--     MOUNTED PWB, D                   SV-6819(AEP)
--------------------------------------------------------------------------------------------------------
---------------
B/M  CHILD-NO....  US      QTY REMARKS           DESCRIPTION
 GRP  HK      SB-NO UDCP                         EXPLS     SEP-NO    ECN-
NO.
11    (A)            M      0  6834,6835
                                                 P--C-           AA751251
11   1-104-660-91    M      3 C6671,6672,6841    CAP, ELECT 47MF/16V
           B6193     -1A-                        P--C-           KV880892
11   1-104-662-91    M      1 C6642              CAP, ELECT 22MF
           B6193     -1A-                        P--C-           KVB30749
11   1-104-664-91    M      3 C6635,6647,6801    CAP, ELECT 47MF
           B6193     -1A-                        P--C-           AA751251
11   1-104-665-91    M      2 C6658,6659         CAP, ELECT 100MF
           B6193     -1A-                        P--C-           AA751251
11   1-107-368-51           2 C6810,6811         CAP, PETP FILM 0.047MF
           C5759     -1--                        P--C-           AA751251
10   1-107-565-11    S      1 C6607              CAP, FILM 0.33MF
  02  GC   D6717     -1--                        P--C-           AA751251
```

-CONTINUE INQUIRY

- Part No. 1-107-368-51 : Position C6810, 6811 : US code shows as "Blank". It means that this is the hand mount part.

- Part No. 1-107-565-11 : Position C6607 : US code shows "S" and the 3rd digit of UDCP code is " - " It means that this is the hand mount part.

- Part No. 1-104-665-91 : Position C6658, 6659 : US code shows "M". It does not Show "Blank" or "S". This is not the hand mount part. It is the auto-mount Part.

The sample of Master BOM is in the table 3.1 whereas the full Master BOM is in the appendix 3.2.

2. According to Hand Mount part list from item 1, the standard operating time is calculated.

The hand mount parts are counted, group by part type. Then multiply number of part of each type by standard operating time as shown in the table 3.2.

3. Calculate manpower from the required quantity and standard operation time from item 2

Required quantity	= 500	boards/day
Standard operating time	= 7.293	minutes
Operating hour	= 8.5	hours/shift
Efficiency	= 80%	

$$\text{Total manpower} = \frac{500 \times 7.293}{8.5 \times 60 \times 0.80} = 8.94 \approx 9 \text{ persons}$$

Table 3.2 : Standard Operating Time Calculation

ST CALCULATION		28FX60		
		D PWB		
Pre-assembly	TIME/UNIT	QTY	TIME	
Heat Sink: Silicone, 1 Screw	0.207	12	2.484	
Heat Sink: Silicone, Spacer	0.125		0	
Heat Sink: Spacer, 1 Screw	0.199		0	
Heat Sink: Silicone, 2 Screws	0.284		0	
Heat Sink: Silicone, 1 Spring	0.18	1	0.18	
Heat Sink: Silicone, 1 Springs 1 Screw	0.262		0	
Total			**2.664**	
INSERTION	TIME/UNIT	QTY	TIME	
C, R, D, JW, L	0.047	54	2.538	
Transistor	0.056	3	0.168	
DB -2.5CM	0.039	29	1.131	
DB -7.5CM	0.05	10	0.5	
DB-7.5CM	0.146	2	0.292	
Single Side Connector	0.036	0	0	
Both Side Connector (2-Assy)	0.069	0	0	
Total		**98**	**4.629**	
GRAND TTL			*7.293*	***min.***

4. Mark hand mount parts on 2 copies of mount drawing

1st copy: mark all hand mount parts shown in the appendix 3.3

2nd copy: mark all position of the same parts with the same color to identify the group of part. This allows to apply the same special treatment easily if any and plan to mount the same part at the same time for simple work flow.

5. Divide the board into 4 equal sections vertically and into 2 equal sections horizontally, as shown in the figure 3.1

6. The parts are sequenced referring to mount drawings from item 4 and sample board based on the concept as follows :

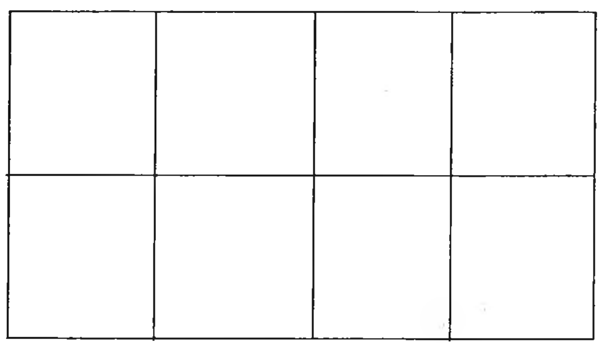


Figure 3.1 : Mounted Zones (Conveyor Type)

6.1 The parts with lock, limp legs or insertion causing the vibration must be inserted first.

6.2 The parts mounted by left and right hand in the same sequence, must be located near each other, so that the operator can focus both in the same time.

6.3 Small part must be inserted before the big one, unless the big part does not obstruct the small one.

6.4 The group of parts, which use same part number, should be inserted in continuous sequence for convenient of part supply. This depends on board design.

6.5 The parts, which have similar appearance or physical characteristic, should be separated.

6.6 Standard operating time of each operation should be approximately equivalent.

6.7 The parts have to be mounted onto the board area where it comes first. It is like "First Come First Serve" concept. This is the constraint of the mounting on the conveyor belt.

The operators are located in serration (zigzag) to optimize the area utilization. The part sequence shall allow mounting the parts on the lower horizontal portion in order to minimize the distance from part box to the mounted location on the board. The number of part inserted by each operator should be equivalent in every area as much as possible. According to the rules above, we will get the part sequence and operator location as shown as the work instruction in the appendix 3.4.

3.1.1.2 Limitation of design sequence

The design sequence of conveyor line, the designer must allocate the equal number of parts to the areas divided horizontally. In order that the location to be mounted is always at the front of operator although the board is moving pass the operator, to minimize the reach and move motion between part box and location to be mounted. The best distribution of parts of #1 operator on the board can be demonstrated as in the figure 3.2.

The limitation of design sequence can create the problems as follows :

- Flexibility

The job balance cannot be simply combined or allocated to adjust the output rate. It is required to re-design the whole hand mount process.

- Waste movement

The part locations on the board are placed depending on the circuit. Then the densities of parts are different area by area, and the similar part is randomly located on the board. These sometimes cannot make the intended sequencing. Hence, this limitation causes the backward or forward sequence, which increase the reach and move motion, then make the operating time of conveyor line longer than it should be.

- Quality improvement

The change of sequence to improve some quality issue is quite difficult because it will have an impact to the total part sequence of workstation.

3.1.1.3 Disadvantages of hand mount process (conveyor belt)

The disadvantages of overall process of the conveyor type can be described as follows :

- Wastes from schedule change due to demand fluctuation or material shortage

- Wastes from intermittent line stop due to different skill operators pushing reset button

- Wastes from stand-by time of experienced operators due to higher speed than the cycle time

- Wastes from high defect rate due to lack of awareness

- Wastes from full line stop even one station stoppage i.e. part mix

- Waste from the part supply job

- Limit in mounting sequence design causing the quality improvement and job balance constraints.

3.1.2 Dip machine

The PWBA on the conveyor belt is fed into the dip machine and the fingers of chain catch the board and carry it through the dipping process. This is automatic process as follows:

- Fluxer:

  - The fluxer applies flux to the board uniformly. When combined with a specific-gravity controller, it can automatically control the flux concentration.

- Preheater:

  - Reduces the heat shock applied when the board and components are dipped into solder, and also prevents the board from warping.

- Vaporizes the flux solvent to ensure that the flux sticks firmly to the board.

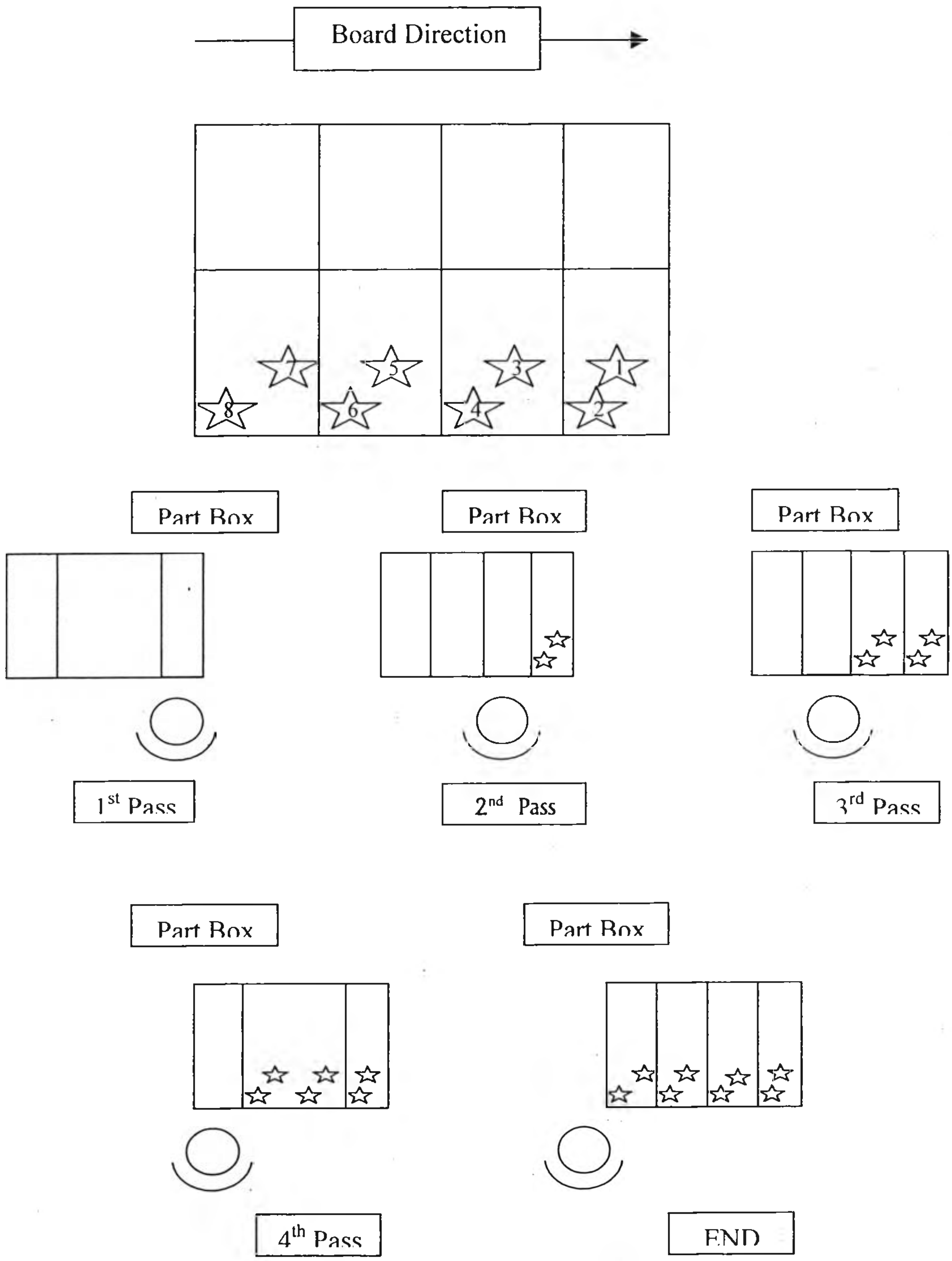


Figure 3.2 : Mounting Sequence Design

- Combines pre-flux (flux applied to the board in advance) with post flux (flux applied to the board using the fluxer in the preceding process

- Solder bath:

  - By means of the solder wave generated by the jet nozzle, many components mounted on the board are automatically soldered to the board, as shown as below. To perform the most appropriate soldering for the board and components, the amount and speed of the solder flow can be adjusted.

- Cooling fan:

  - Cools the soldered portions and soldered components

  - Reduces warping of the board

As above-mentioned, this is an automatic process so this is not much related to this research as it is 100% automatic process.

3.1.3 Touch up

This is a process to do an visual mechanical defect and fast rework on the minor defect as necessary like solder bridging, cleaning solder ball.

The operator does the visual inspection board by board. The operator has to pick up the board from the conveyor belt and place the board back after finish the inspection.

The disadvantage is the movement waste of picking & placing boards. In addition, the inspection job for the whole board is too fatigued causing inferior detection ability of operators.

3.1.4 In-Circuit-Test process

This is the test equipment to check the electrical components whether they are mounted correctly. The defects are like reversed polarity, missing part, short circuit, open circuit etc. The ability of the detection is around 80-95% of components mounted on the board. The quality of the board still needs the accuracy of hand mount process as it shall follow "Do it right the first time" concept.

The disadvantages are as follows:

- The idle time of operators exist during the processing time of the tester.
- The stock of the board is plied up if there is some tester problem.
- Operators try to perform their jobs in time without concern of the rejected rate causing continuous defects.

3.1.5 Circuit-Board-Adjustment

This is the equipment to set the electrical value for some components on the board such as the response frequency, bias voltage etc. In terms of productivity impact, the waiting time during the equipment processing time shall be utilized.

The disadvantages are the same as ICT process.

3.1.6 Final inspection

This is a visual inspection process. The board is inspected on the critical criteria that the test process cannot detect.

The disadvantage is work overload/idle time depending upon the line condition causing defects escaped or drop of productivity.

3.1.7 Packing

The finished boards are packed into the carton box with cushion foams to prevent the damage during the transportation.

The disadvantage is the balance of the workload within the process and also the fluctuation of the line condition that affects the job load.

3.2 Existing problems

Based on a conveyor belt line design, there are several difficulties that we have encountered. They cause the production line become inferior performance. The production performance is measured by Operational Productivity Index. The poor productivity causes can be breakdown in categories as follows:

1. Schedule change

The production demand is fluctuated because the computer business is changed so fast as the product life is around 6 months. The order is varied from month to month depending the market situation. The workstations have been fixed along the long conveyor belt. To adjust the output rate needs a lot of change in line layout. Once, there is a drop of customer order, the excess capacity is inevitable causing idle operators.

This problem also can exist in the daily production when there are some obstacles that have impact to the production schedule such as raw material's delay, high absence of operators. The conveyor line cannot give the flexibility causing the drop of productivity.

2. Quality issue

There are a lot of defects after passed the dip machine and plying up. The information flow is not so effective for the continuous production due to the running of conveyor belt. The front line operation continues to build the defect board without realizing the quality of finished boards.

3. High idle time

When one operator cannot finish a job within the cycle time that is controlled by the belt speed, the operator has to push the reset switch to stop the conveyor belt. This causes the whole line to wait only one operator that is huge idle time.

This is mainly from the new operators that don't have enough skill. This condition cannot be avoided due to the replacement of resigned operators or operators' allocation among the production lines.

The company has faced the high turn over ratio because the temporary operators have been recruited instead of permanent operators due to flexibility reason. The skill of operators cannot be stabilized.

4. Sluggish Improvement

The output is determined by the speed of conveyor belt. This causes a lack of improvement opportunity because the operators are blocked their improvement by the speed of the conveyor belt. There is a ceiling of the output rate since started up the line. To adjust the speed of the belt to match the operators' capability is difficult in practical work.

5. High Inventory

The Work-In-Process is built up without concern of the production line condition. There may be a trouble spot at somewhere in the production line causing the bottleneck. If the conveyor belt is still continued running, the WIP is plied up at the bottleneck due to un-smooth flow. This causes an uncontrolled inventory level in the production line because the problem cannot be recognized and solved.

6. Changeover loss

There is a chance to build the different models in parallel on the same production line. This can eliminate the changeover loss. The process that gets the most impact from the model change is the Hand-Mount process. The part boxes' location and the length of the conveyor line is fixed so only one model can be run at the time. With cell concept, the Hand-Mount process can be divided into many cells and each cell can be assigned one model. It becomes multi-models in the line.

3.3 Current results

3.3.1 Selection of productivity index

The index to be used in this research is the operational productivity (OP) as stated in the Chapter I. The reason why this index is selected for this research is from the definition of itself that can reflect actual effectiveness of the operation as explained below.

There are 3 indexes to measure the productivity in the company. They are : (1) total operational productivity, (2) operational productivity and (3) operator efficiency. Figure 3.4 shows the formation of work hours. and the figure 3.3 shows the diagram of these 3 indices

1. Total Operational Productivity (TOP) : this index is the comparison between the standard time (headquarters' normal time) and actual man-hours that means the possible man-hours subtracted with the late, absent and early leave. The effect of waste time is all included in this index such as the late transportation, meeting time, training time and house keeping time. This kind of waste time is so called "invalid time". This index cannot reflect directly to the effectiveness of process and quality improvement. It may be dropped down by inefficient transportation that causes operators start to work late so it is not related to the process.

$$TOP = \frac{\text{Standard Time} * 100}{\text{Total Hours - (Late, absent, early leave)}} (\%)$$

2. Operational Productivity (OP) : this is the productivity index that deducts the invalid time in TOP. Any waste time in the processes are taken account for this index calculation. According to the figure 3.3, the waste times that affect to this index are repair work hours, preparing work hours, idle hours and repair. In case of any special request from the design centre to modify/rework the product, this work hour must be deducted has no impact to this OP index.

$$OP = \frac{\text{Standard Time} * 100}{\text{Total Available Hours - Invalid Hours}} (\%)$$

Total Available Hours = Total Hours – (Late, Absent, early leave)

This index can show the actual performance of the operation at front line level.

3. Operator Efficiency (OE) : all downtime is excluded for this OE index. The man-hours remain only the actual time that operators spend to work. This index can reflect the performance of operators. In this research, the processes are improved as a major expectation to enhance the productivity so the OE is not appropriate for the result measurement.

$$OE = \frac{\text{Standard Time} * 100}{\text{Production Hours - (Repair hours, idle hours, prepare hours)}} (\%)$$

Basically, the non-production hours and modified hours by internal company are zero so the formula can be written as above.

The detail of these 3 indices can be found in the appendix 1.1 : SS Technical standard.

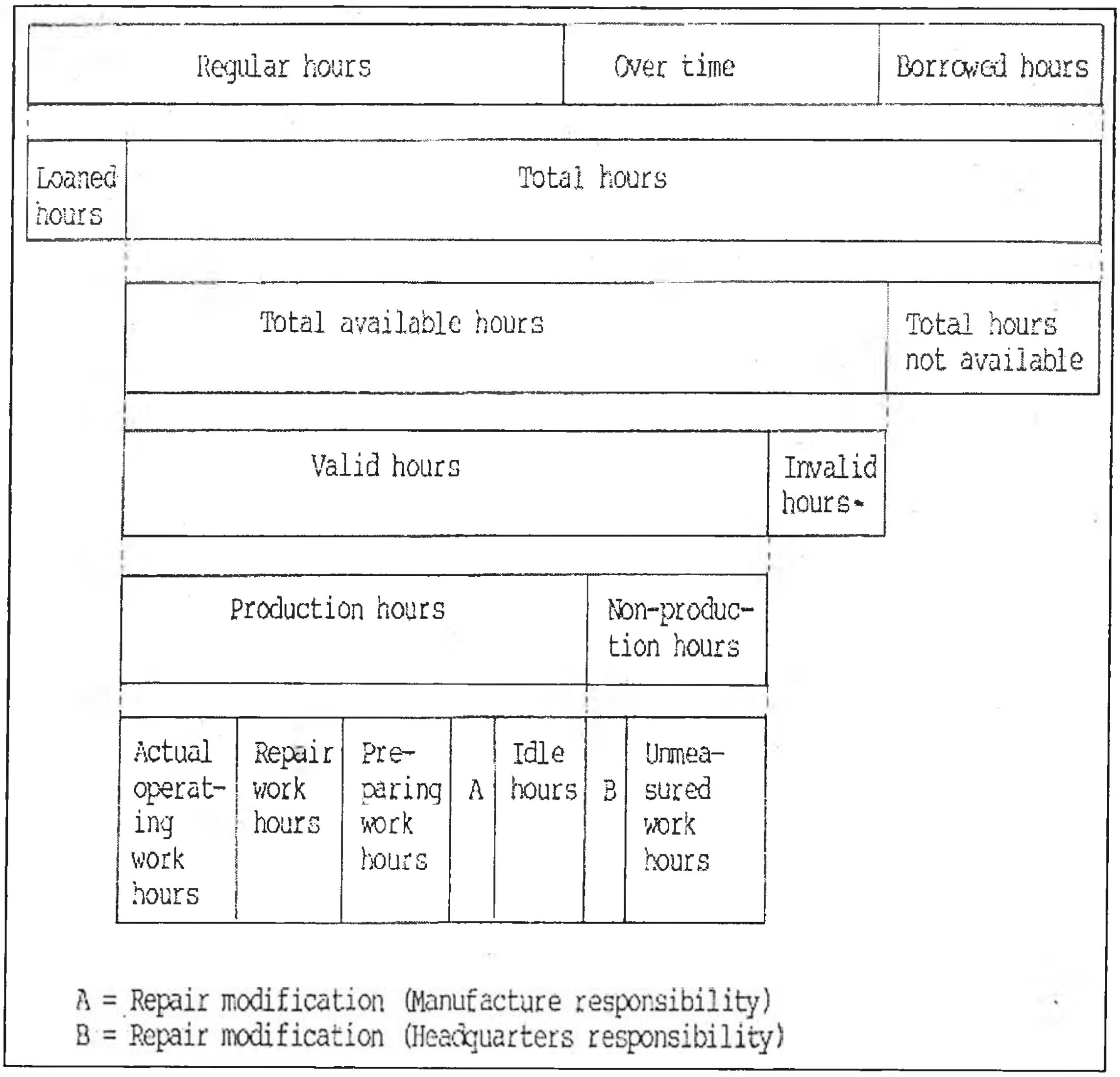


Figure 3.3 : Formation of work hours

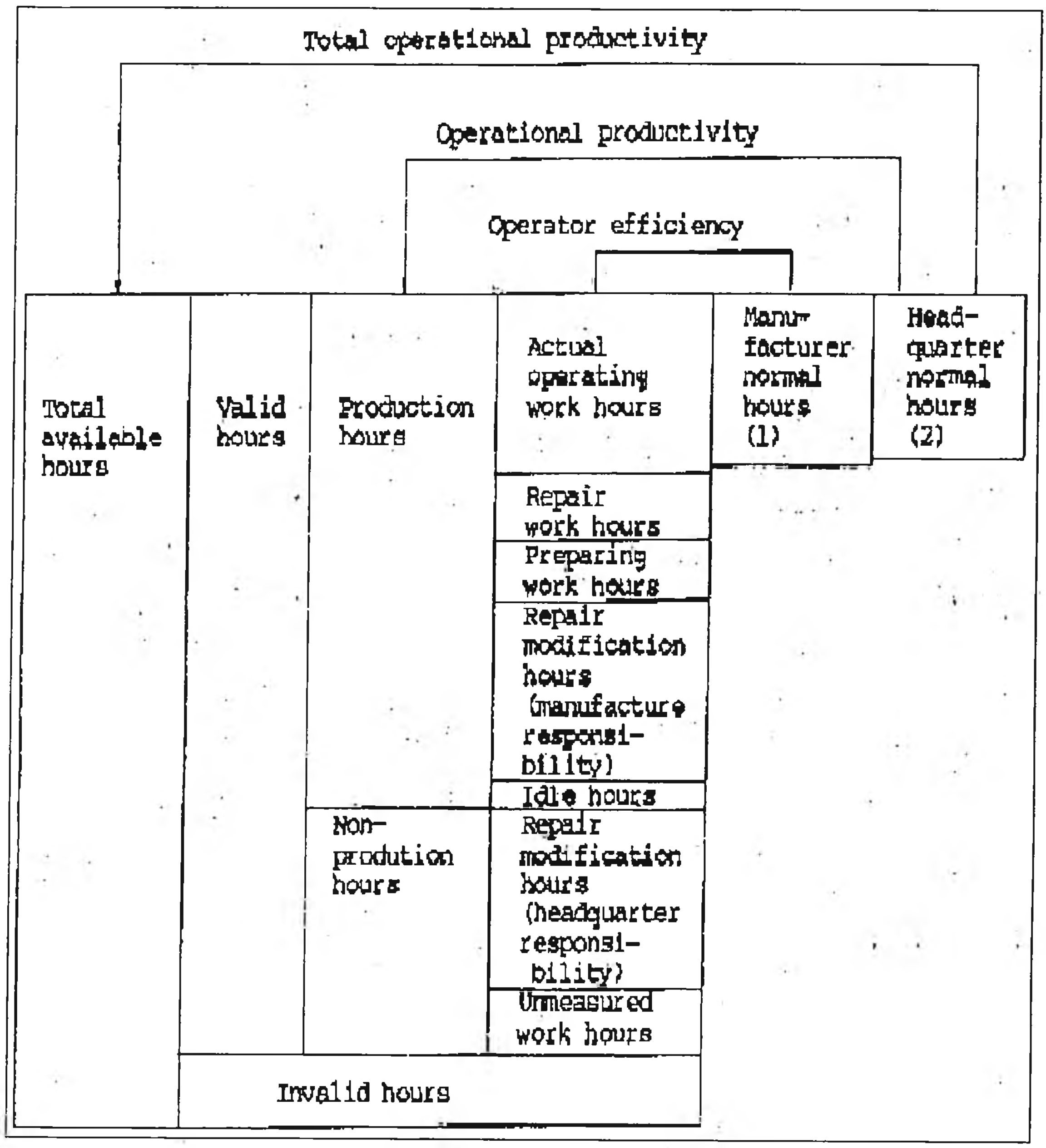


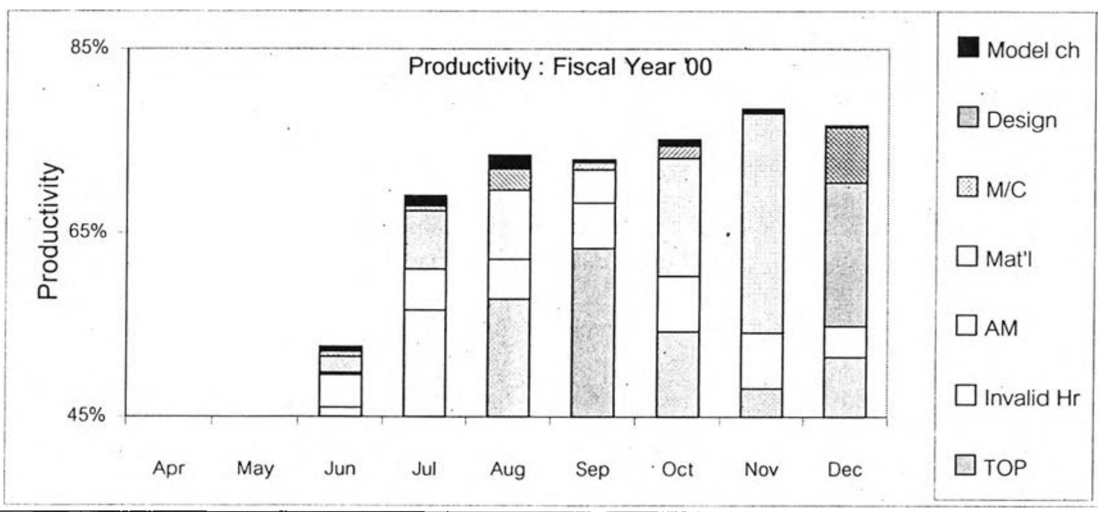
Figure 3.4 : Productivity Index Diagram

This data is collected by daily. The operators fill in the form for all waste time categories such as 5S (house keeping time), morning meeting, equipment downtime, material short supply. There is a program in Microsoft Access platform to calculate the TOP, OP and OE after operator put all parameters into the program.

The format of the work hours report is shown in the appendix 3.5.

3.3.2 Productivity index

Figure 3.5 is shown the productivity result of the conveyor line operation.



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

Figure 3.5 : Monthly Productivity

The productivity data in the form of work hours is shown in the appendix 3.6 that is printed out from the database. The Operational Productivity (OP) is low. The causes of the line stoppage are shown the 1st column on the left side. The main impact is from the material category that may be in shortage or un-smooth supply. The flexible operation shall be able to absorb the fluctuation factors.

3.3.3 Quality index

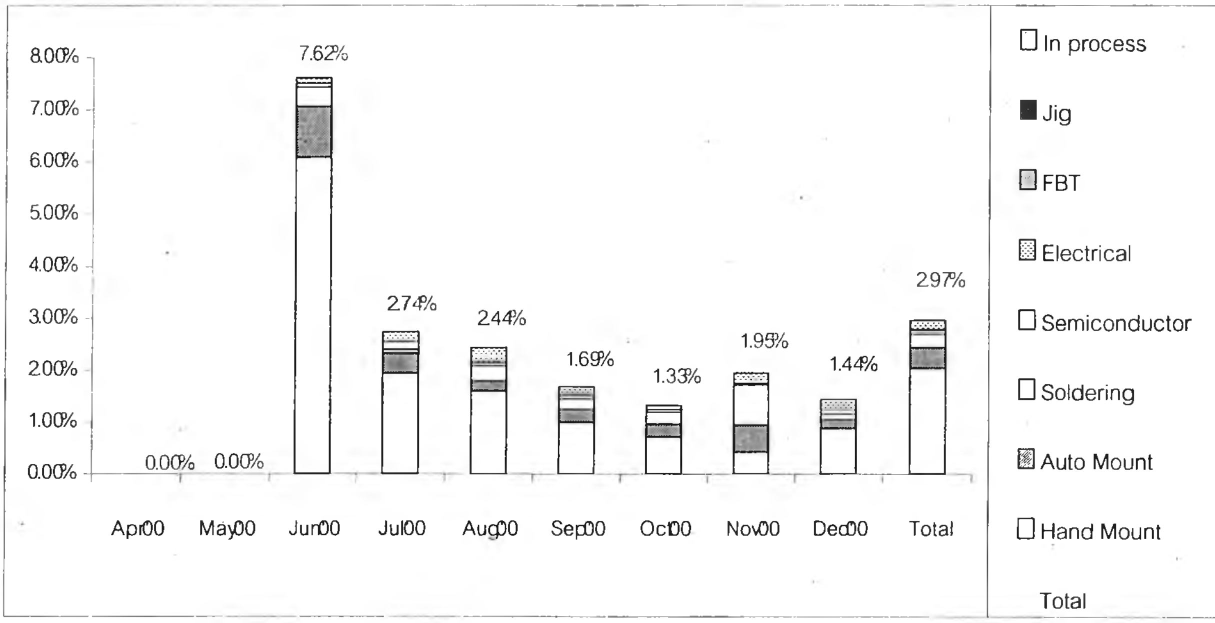
The line design and shop floor control system also contributes to the quality performance. The average ICT defect from starting to Dec '2000 is 2.97% that is 2 % from the hand mount defect

The hand mount defect is typically treated as the human error defect but this is not always true because there are other factors causing the operators' error. The difficulties in working method can cause operators potentially creating the defects. The abnormal condition of the production line is ignored by the support people unintentionally because the production line still keeps going by the conveyor belt even the quality issue taking place.

The CBA defect is much lower than the ICT defect because all defects have been detected and repaired at ICT process. Some defects only that affect the functional board can be rejected by CBA process. The hand mount defect is still the major defect of this CBA process.

The data of defects are collected from the repair technicians. After the technicians repair the rejected boards, they fill in the data into the form. The defects are categorized into codes for the computer input. The defect database also uses Microsoft Access for manipulate the data. The record format of the daily repair record is shown in the appendix 3.7.

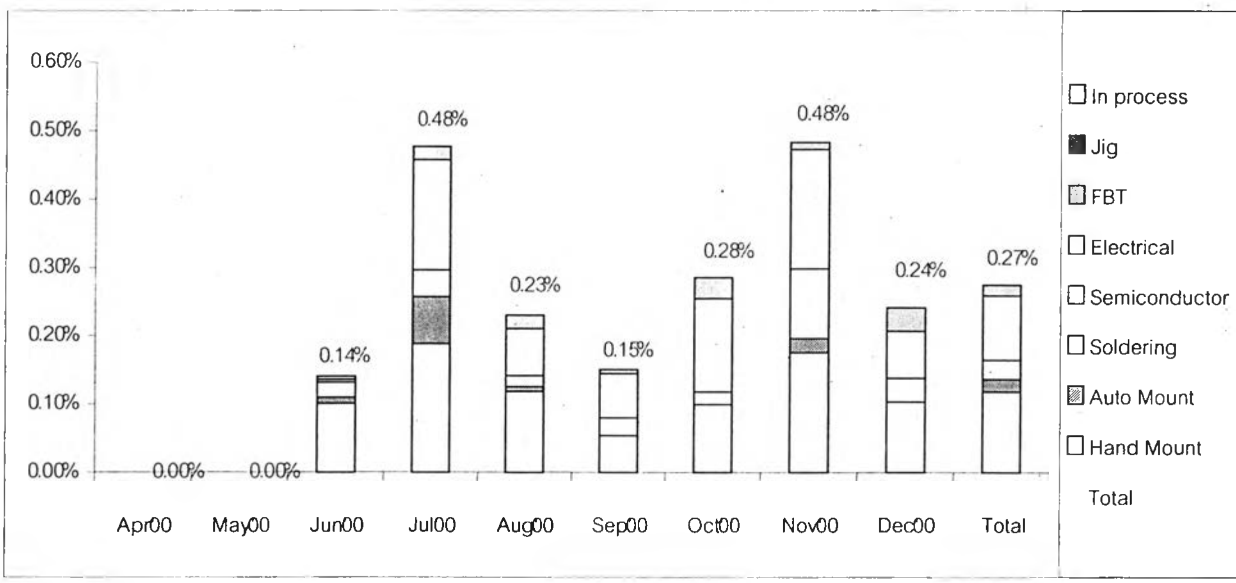
PWBA (AE5) MONTHLY ICT DEFECT RATIO



Wee	Apr00		May00		Jun00		Jul00		Aug00		Sep00		Oct00		Nov00		Dec00		Tota	
OUTPU	0		0		2283		3040		3046		2993		1614		973		581		14533	
DEFEC	0		0		173		834		744		505		214		190		84		431	
%DEFEC	0		0		7.62%		2.74%		2.44%		1.69%		1.33%		1.95%		1.44%		2.97%	
CAUS/RES	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def
Hand	0	0	0	0	139	6.09%	589	1.94%	485	1.59%	299	1.00%	114	0.71%	41	0.42%	51	0.88%	296	2.04%
Auto	0	0	0	0	223	0.98%	118	0.39%	62	0.20%	76	0.25%	41	0.25%	51	0.52%	10	0.17%	581	0.40%
Solderin	0	0	0	0	84	0.37%	24	0.08%	88	0.29%	59	0.20%	38	0.24%	75	0.77%	6	0.10%	374	0.26%
Semiconduc	0	0	0	0	17	0.07%	45	0.15%	21	0.07%	20	0.07%	8	0.05%	3	0.03%	5	0.09%	119	0.08%
Electric	0	0	0	0	25	0.11%	58	0.19%	87	0.29%	50	0.17%	13	0.08%	20	0.21%	12	0.21%	265	0.18%
Tune	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Touc-up	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
FB	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Jig	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Inprocess	0	0	0	0	0	0.00%	0	0.00%	1	0.00%	1	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.00%
Re . OK	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.01%	3	0.03%	4	0.07%	8	0.01%

Figure 3.6 : Monthly ICT Defect

PWBA (AE5) MONTHLY CBA DEFECT RATIO



Wee	Apr00		May00		Jun00		Jul00		Aug00		Sep00		Oct00		Nov00		Dec00		Tota	
OUTPU	0		0		2263		3040		3046		2933		1614		973		581		14533	
DEFEC	0		0		32		14		70		45		46		47		14		39	
%DEFEC	0		0		0.14%		0.48%		0.23%		0.15%		0.28%		0.48%		0.24%		0.27%	
CAUSRES	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def	Q't	%Def
Hand	0	0	0	0	23	0.10%	57	0.19%	36	0.12%	16	0.05%	16	0.10%	17	0.17%	6	0.10%	17	0.12%
Auto	0	0	0	0	2	0.01%	21	0.07%	2	0.01%	0	0.00%	0	0.00%	2	0.02%	0	0.00%	27	0.02%
Solderin	0	0	0	0	0	0.00%	12	0.04%	5	0.02%	8	0.03%	3	0.02%	10	0.10%	2	0.03%	40	0.03%
Semicondu	0	0	0	0	5	0.02%	49	0.16%	21	0.07%	19	0.06%	22	0.14%	17	0.17%	4	0.07%	13	0.09%
Electric	0	0	0	0	1	0.00%	6	0.02%	6	0.02%	2	0.01%	5	0.03%	1	0.01%	2	0.03%	23	0.02%
Tune	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Toucup	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
FB	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Jig	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Inprocess	0	0	0	0	1	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Re .OK	0	0	0	0	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%

Figure 3.7 : Monthly CBA Defect