MATERIAL AND METHODS

Materials

The material and resources of this thesis can be categorized into three groups; Hardware, Software, and Data input. Detail information regarding each group is listed as below:

1. Hardware

1.1 Personal computer: Computer Pentium III 700 with 640 MB Ram
It is necessary to choose a computer with a proper specification.

1.1.1   Window 95/98 or window NT

1.1.2   CPU 80486 or Pentium 166 or more

1.1.3   Ram 16 MB

1.1.4   VGA monitor of higher resolution

1.1.5   CD-ROM

1.1.6   Free hard disk spaces at least 512 MB

1.2 Printer Black & white or color

2. Software

2.1 Program Microsoft Excels version 2000

2.2 Program Microsoft Word is used to create this research document.

2.3 Visual Basic

3. <u>Data Input</u>

3.1 Standard time for each operation

3.2 Number of jobs to be processed on machine

3.3 Manpower requirement for each machine

3.4 Number of machines in production environment

3.5 Number of batch size of jobs

3.6 Number of workers available

<u>Methods</u>

The method employed is based on the problem solving process as follows;

1. Problem formulation.
2. Data collection.
3. Proposed dispatching rules for job scheduling.
4. Heuristics rules for workforce scheduling.
5. Solving the heuristic algorithm.
6. Analysis of output.
7. Conclusion and recommendation.

1. <u>Problem formulation</u>

This research was conducted using data from a metal can manufacturing company which designs and manufactures several kinds of cans over decades of accumulated experience. Although the company produces many types of product such as aerosol cans, food can, all-purpose round cans, rectangular can, pails and cups, etc., but the highest volume of sales are mainly concentrate in the general round can and rectangular cans which constitute to around 80% of the total production.

Table 3 8 Main Product Ranges.

Types of product	
1. **Aerosol cans**	
2. **General round cans**	
3. **Food can**	
4. **Rectangular can**	
5. **Gallon pail**	

Table 3   (Cont'd)

Types of product
6.   Cup
7.   Rectangular pails
8.   Top accessories

All products go through similar processes although somewhat different in minor details. The overall process can be divided into three main production processes as follows;

1. Printing and body forming process: to print logo and patterns onto a flat sheet of tin and cutting into can body. The body is then formed into a cylindrical shape before sending it to the final assemble.

2. Pre-assembly process: cutting and stamping the metal sheet into the desired shapes to become lids, bottom, rings and handles.

3. Final assembly process: piecing the components together into final products.

The printing process is a sophisticate fully automated process which can accommodate numerous orders in daily production. The final assembly process is also a continuous production line which employs a software for production planning and control in order to meet the daily customer orders. Hence problem lies in the pre-assembly process where there are only two types of machines, press and seal, both are manually operated and need a worker for each machine. There are 40 press machines and 15 seal machines available for all jobs, but there are not enough workers for all the machines.

From the observation, the workers in pre-assembly department are allocated to each machine on a random basis and assumed that each worker can work in all machines. The worker duties are not only to operate on the machine but also to check quality of parts while working. There is a high variation in operation time due to different levels of skill of workers.

The production planning in this company employs a backward scheduling approach that is plan from the final assembly stage to meet delivery due dates and send the plan to pre-assembly department. However due to high variation in the processing time and high number of jobs in the pre-assembly, the production of parts are always delay and thus plans do not meet targets. Problems in the delay of production in the pre-assembly department are due to;

1. There are not enough number of workers for all the jobs and machines.
2. There is no differentiation in the skill levels of each worker while there are different types of machine.
3. There are high turnover ratios of worker causing further problem in the productivity drop due to learning cycle of new workers.
4. The processing time used in the planning of pre-production is a single value from an estimate and does not represent the actual production of different product parts or different operations.

The problem in the pre-assembly department of this company is a classic 2 steps scheduling situation. Step one is the scheduling of jobs to machines and step two is the scheduling of workers to the allocated jobs. This thesis will investigate the effects of skill levels on the improvement of production schedule using heuristic rules.

2. **Data gathering**

There are 4 main groups of data to be used as input and testing of the 2-step scheduling method as follow;

2.1   Product data

2.2   Production Process data

2.3   Types of Machine

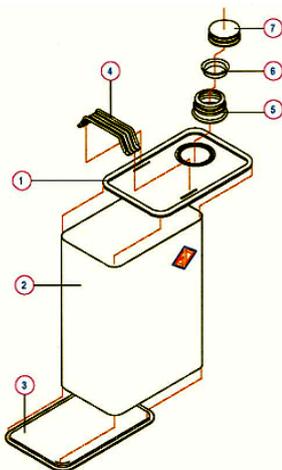2.4   Standard time for each production process

2.1   Product Data

The products which pass through pre-assembly process can be generalized into two types namely; general round cans and rectangular cans. Details of part assembly for both general round cans and rectangular cans are shown in figure 5 and 6.
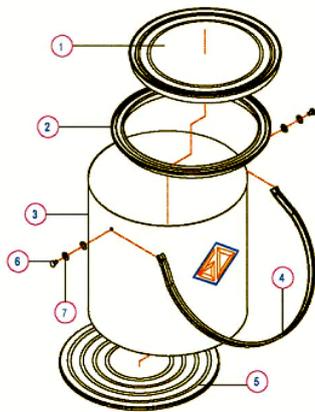
No.	Details
1	**Cover:** a can's lid or closure and some type of cover have **Curl:** area of tin turned in on itself to provide a safe, finished curved edge
2	**Multiple or single friction (Ring) :** a plug closure fits into a "well" of a seamed-on ring. The plug is pressed into the ring and the two surfaces (the outside and inside edge) come into contact with the ring, creating multiple sealing surfaces on the plug/ring combination
3	**Body:** a can without a cover (lid); the base of a container
4	**Handle**
5	**Bottom or can end**
6	**Nut**
7	**Attach ear**

Figure 5 General Round Can.

No.	Details
1	**Cover:** a can's lid or closure
2	**Body:** a can without a cover (lid); the base of a container
3	**Bottom**
4	**Handle**
5	**Thread**
6	**Inner-cap**
7	**Cap**

Figure 6 Rectangular Can.

     Although both products has numerous parts, but there are only 4 parts which are made in the pre-assembly lines, namely lid, bottom, ring and handle. There are also various sizes and height of round and rectangular cans which can be grouped into 6 family codes, each code has different production process and different processing time. For the purpose of the study, all the product information are classified into 6 family codes as follows:

Table 4 Products in the 6 Family Groups.

Group	Product Code	Type	Height	Size	Parts for Pre-Assm.
1	2GC1 , 2GC6-1	General Round Cans	Low	1 Gallon	4
2	2GC5 , 2GC6-5	General Round Cans	High	1 Gallon	3
3	2GC2L ,2GC6-2L	General Round Cans	Low	1/4 Gallon	3
4	2GC2H , 2GC6-2H	General Round Cans	High	1/4 Gallon	3
5	2GR3	Rectangular Cans	-	1 Gallon	3
6	2GR4	Rectangular Cans	-	1/4 Gallon	3

2.2 Production Process data

     The pre-assembly line consists of two simple processes namely pressing and sealing.
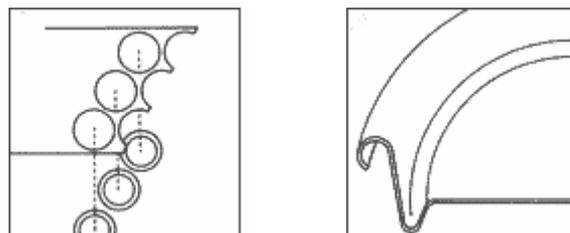

Figure 7   Press process of lid.

Sheet metal passes through the press machine in the first process and cut the metal into desire shape while in the mean time curl the edge of the piece as shown.
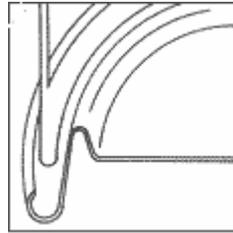

Figure 8   Sealing with rubber compound.

The newly formed ends the are passed through the second stage, sealing where a lining machine applies a very precise bead of compound sealant around the inside of the curl.

All classes of product family can be grouped into three production processes as follows;

Production process 1

PRESS   **SEAL**

Top can

Stock and
Final assembly line

- -

Bottom can

Stock and
Final assembly line

- -

Ring can

Stock and
Final assembly line

- -

Handle

Stock and
Final assembly line
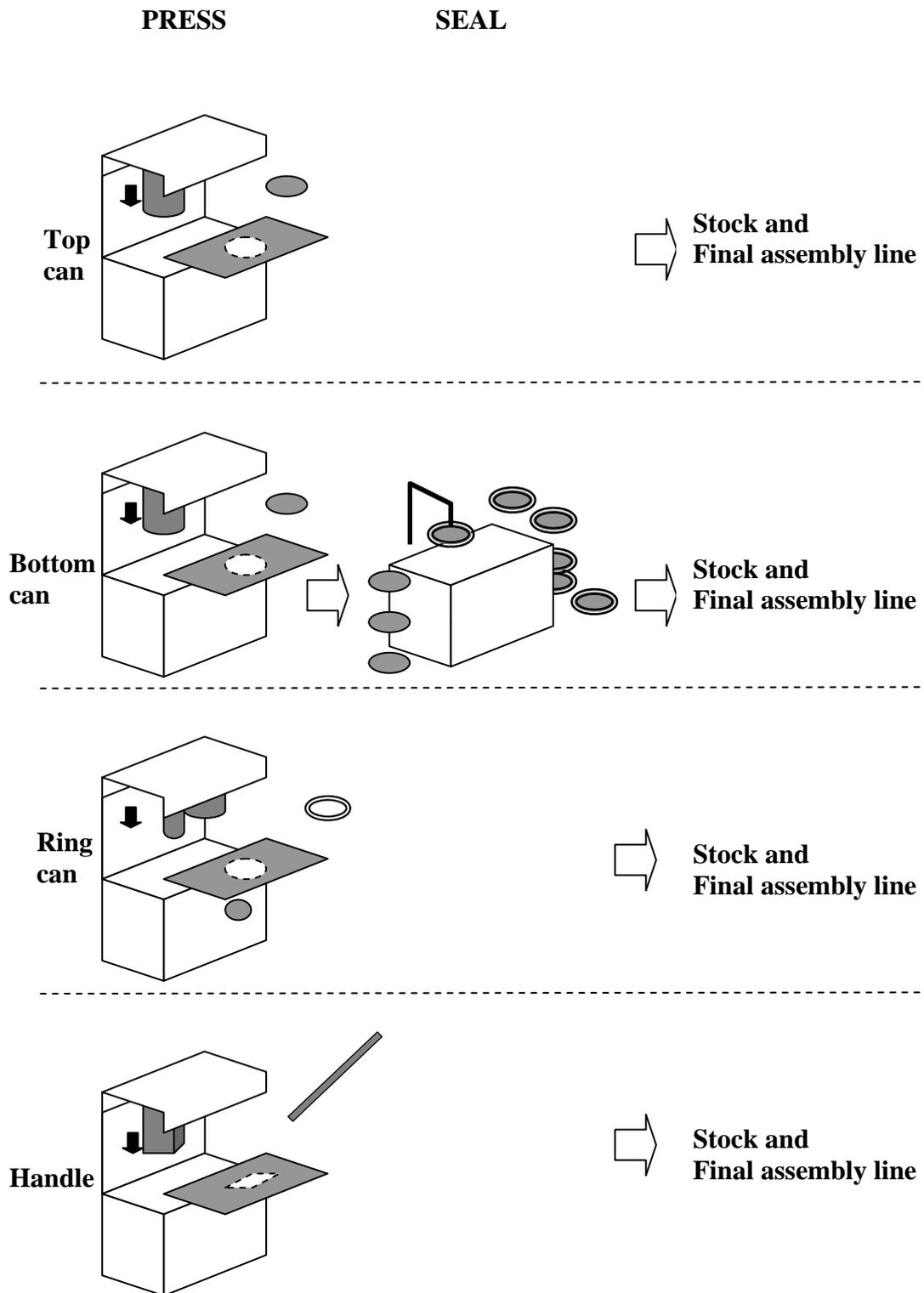
Figure 9 Production Process for Product Class 1- General Round Cans.

Production process 2

PRESS　　　　　**SEAL**

Top can → Stock and Final assembly line

Bottom can → Stock and Final assembly line
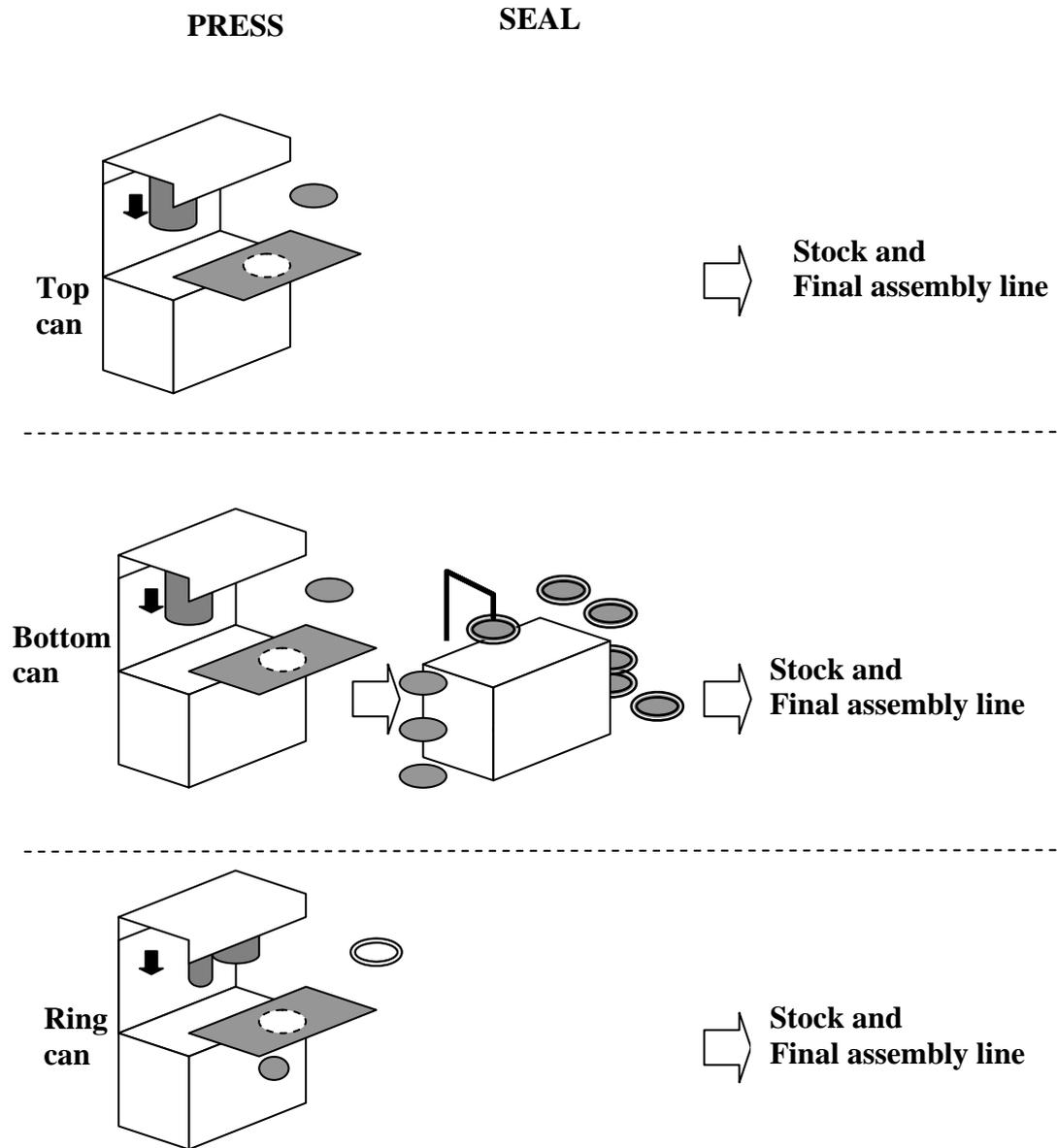
Ring can → Stock and Final assembly line

Figure 10   Production Process for Product Class 2-4 General Round Cans

The processes of class 2-4 are the same with exception of some processes are performed with different type of machines.

Production process 3

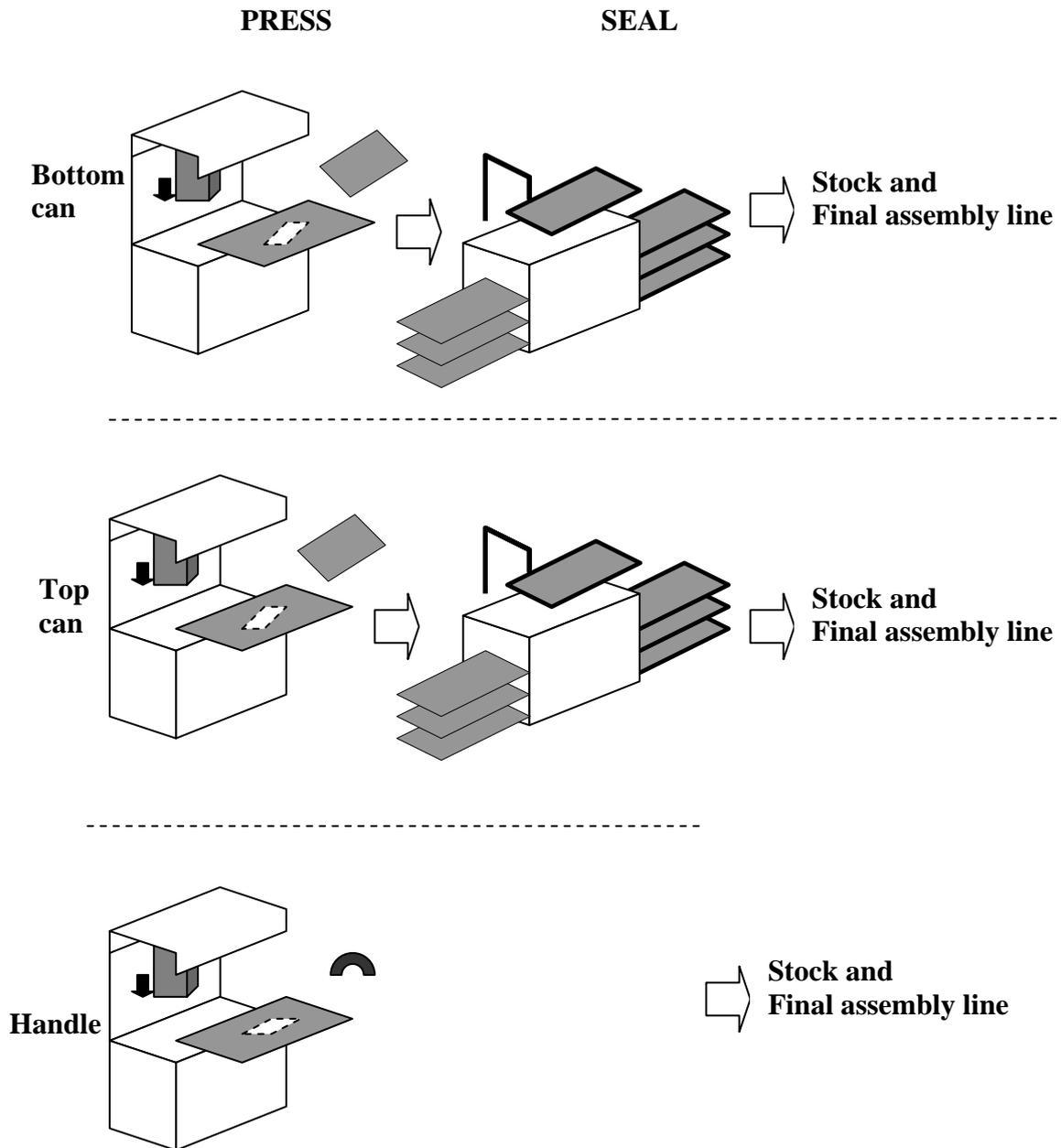**PRESS**　　　　　　　　　　　**SEAL**

Figure 11 Production Process for Product Class 5-6 Rectangular Cans

The processes of class 5-6 (Rectangular Cans size 1 and ¼) Gallon are the same but using different type of machines.

2.3 Types of Machine

Although there are 40 press machines and 15 seal machines available for all jobs, but each machine is set up for one product part in order to reduce set up time. Hence it needs only 27 machines for the parts under this study. For simplification, machine codes will be allocated as shown in the table 5.

Table 5 List of machines for general round can and rectangular can.

Machine Code	Types of machines	Product Type	Height	Size	Part
pt1	Press	General Round Cans	Low	1 Gallon	Top
pb1					Bottom
pr1					Ring
ph1					Handle
pt2	Press	General Round Cans	High	1 Gallon	Top
pb2					Bottom
pr2					Ring
pt3	Press	General Round Cans	Low	1/4 Gallon	Top
pb3					Bottom
pr3					Ring
pt4	Press	General Round Cans	High	1/4 Gallon	Top
pb4					Bottom
pr4					Ring
pt5	Press	Rectangular Cans	-	1 Gallon	Top
pb5					Bottom
ph5					Handle
pt6	Press	Rectangular Cans	-	1/4 Gallon	Top
pb6					Bottom
ph6					Handle

Table 5 (Cont'd)

Machine No.	Types of machines	Type	Height	Size	Part
sb1	Seal	General Round Cans	Low	1 Gallon	Bottom
sb2		General Round Cans	High	1 Gallon	Bottom
sb3		General Round Cans	Low	1/4 Gallon	Bottom
sb4		General Round Cans	High	1/4 Gallon	Bottom
st5		Rectangular Cans	-	1 Gallon	Top
sb5					Bottom
st6		Rectangular Cans	-	1/4 Gallon	Top
sb6					Bottom

2.4 Standard time

Processing time for each production process is collected by using the method of time study. Each operation is timed for 20 cycles and relative accuracy is calculated to be ± 10% within 95 % of confidence intervals.

Standard time is calculated as follows;

Standard time   =   (Average time x Rating factor) + Allowances

where Average time is calculated from 20 observations. A 15% allowance is applied throughout.

Since one operator is allowed to operate on one machine, there are assumed that 27 operators are to be used.

Table 6 Summary of Standard Times for each Operation

Class	Press (M1)	Std. time	Seal (M2)	Std. time	Part
Class1	Top	2.97			Top
	Bottom	4.12	Bottom	3.79	Bottom
	Ring	5.67			Ring
	Handle	6.58			Handle
Class2	Top	3.42			Top
	Bottom	3.93	Bottom	2.91	Bottom
	Ring	4.14			Ring
Class3	Top	3.77			Top
	Bottom	3.52	Bottom	2.76	Bottom
	Ring	4.99			Ring
Class4	Top	3.85			Top
	Bottom	2.84	Bottom	2.09	Bottom
	Ring	5.28			Ring
Class5	Top	3.28	Top	5.00	Top
	Bottom	4.11	Bottom	4.72	Bottom
	Handle	6.16			Handle
Class6	Top	4.3	Top	6.62	Top
	Bottom	4.68	Bottom	4.60	Bottom
	Handle	5.78			Handle
Total	19 Press machines		8 Seal machines		19 parts

3. **Phase I : Job Sequencing**

Since there more machines than operators available for the jobs, it is logical to assign jobs to machines first and then assign operators to machines. This problem will be divided into two phases namely; job scheduling and worker scheduling. The first phase will consider job scheduling by considering different dispatching rules in a two stage parallel machines with the objective of minimizing maximum completion time of all jobs.

Proposed dispatching rules for job scheduling

In a sequencing and scheduling problem, dispatching rules set priority to all the jobs that are waiting for processing on any machine. Whenever a machine is available, a dispatching rule inspects the waiting jobs and selects the job with the highest priority. There had been several studies in dispatching rules in the past, the related rules to the completion time constraints can be described as below;

1. First-In-First-Out (FIFO): Selects the jobs in the order of their arrival times; very simple and robust; it is the most commonly used rule by workflow systems.

2. Earliest Due date (EDD): Selects the job with the nearest due date; it is known to be effective in minimizing the system's mean total tardiness.

3. Shortest Processing Time (SPT): This rule schedules the jobs in the order of increasing processing time. Whenever a machine is free, the shortest job available at the time will begin processing first. This algorithm is optimal for finding the minimum total completion time and weighted completion time.

4 Longest processing time (LPT): This rule schedules the jobs in the order of decreasing processing times. Whenever a machine is free, the largest job ready at the time will begin processing first.

5 Johnson's algorithm: This algorithm minimizes the makespan in a flow shop, given all job are available at the beginning and non-preemption. In a two-stage flow shop, this rule looks at all jobs on both stages at the same time and set priority based on the shortest processing time. It is based on the rule that says job i should precede before job j if min $\{ t_{i1}, t_{j2} \} <= \{ t_{i2}, t_{j1} \}$, where t_{i1} is the processing time of job i on machine 1, t_{j2} is the processing time of job j on machine 2. The rule sets for the shortest processing time to be processed first in stage 1, and the shortest processing time to be processed last if in stage 2.

Johnson's rule is not applicable in the situation where number of machines in two stages are not equal.

6 Genetic Algorithms: This algorithms as a search process at each iterative step, a number of different schedules are generated and carried over to the next step by combining with the sequence of operations on another machine in another parent schedule. Actually, the genetic algorithm can be applied to problem without having to know much about the structural properties of problem. However, the amount of computation time needed to obtain the solution can be relatively long in comparative with the more rigorous problem specific approaches such as dispatching rules.

In this study basic concept of dispatching rules is used for single machine. In the first phase, several dispatching rules are proposed such as ; FIFO , SPT , EDD, and LPT. This is a 2 stage parallel flow shop and the objective is to minimize the maximum total production time of stage 1 and stage 2 (M1+M2) for each parts in class.
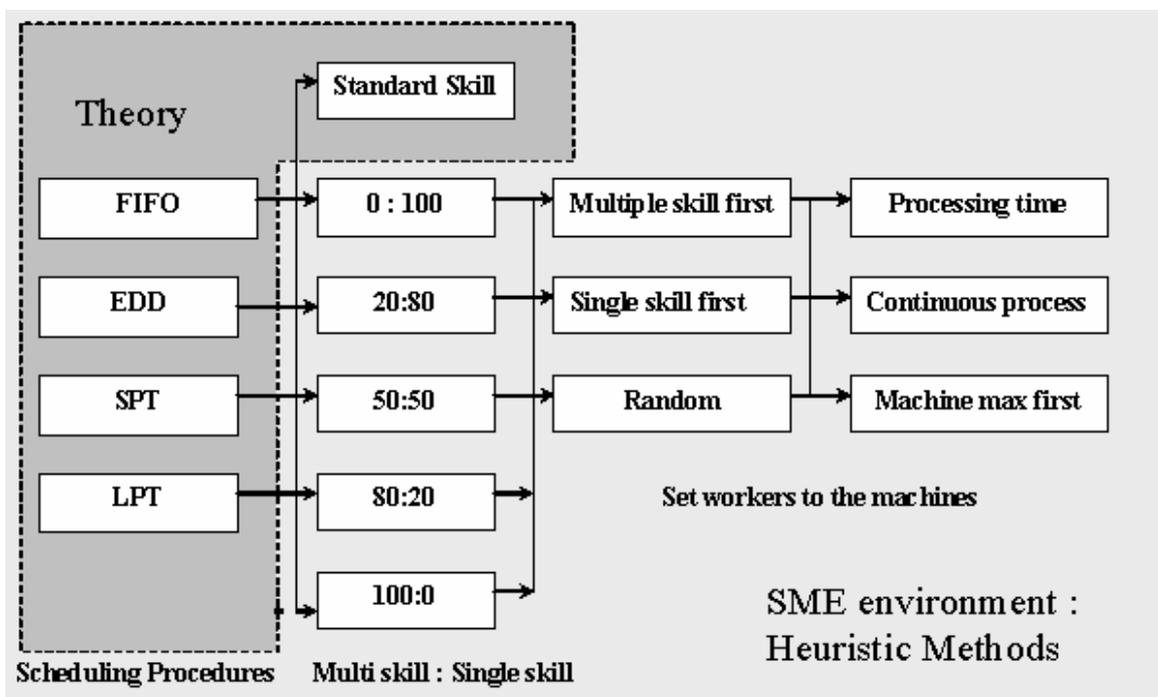

Figure 12 The concept and scope of the thesis

Before starting the job sequencing on the machines, there are certain assumptions to be made.

- Processing time for each job is standard time for experienced workers
- Since each machine is a simple process machine, thus set up time is considered to be negligible.
- There are more jobs than the number of machines
- Each job can be assign to only one machine and one operator to one machine at a time.
- All jobs are of same priority.

The problem can be stated as follows. A set of n jobs is available at time 0 to be processed by two machines where each job is processed on machine 1 first and then on machine 2. All jobs follow the same unidirectional flow pattern through the shop.

Hence the objective function is as follow:

$$\text{Min. } C_{max} \ = \ \text{Min} \sum_{j=1}^{n} C_{2,j}$$

Subject to the following constraints,

$$C_{1,j} \geq P_{k,j} \qquad\qquad \forall j, \qquad (1)$$

$$C_{2,j} \geq C_{1,j} + P_{2,j} \qquad\qquad \forall j, \qquad (2)$$

$$C_{1,j} - P_{1,j} \geq C_{1,j} \ \vee \ C_{1,j} - P_{1,j} \geq C_{1,j} \qquad \forall i,j, \ i \neq j, \quad (3)$$

$$C_{2,j} - P_{2,j} \geq C_{2,j} \ \vee \ C_{2,j} - P_{2,j} \geq C_{2,j} \qquad \forall i,j, \ i \neq j, \quad (4)$$

where,

$C_{k,j}$ be the completion time of job j on machine k.

$P_{k,j}$ the processing time of job j on machine k (for $j = 1,\ldots,$n and $k = 1,2$)

(1) means there is no jobs being processed on machine 1 before time 0,

(2) requires for each job must complete the first stage before it can go through the second stage,

(3) and (4) indicates that machine in both stages can not process more than one job at a time.

In order to explain how the dispatching rules are applied in the job scheduling in this phase, a step by step example will be presented as follows.

1) Considering the case of a general round can product class2 where there are 3 pieces to be manufactured lid , bottom and handle, while a rectangular can line of class5 also consists of 3 parts; lid , bottom and handle. The processing time of each part are listed on table 7 and table 8.

Table 7 General round can line data.

M 1	M2	Part of general round can
press-top Std. time = 3 second.		→ TOP CAN
press-bottom Std. time = 4 second.	→ sealing-bottom Std. time = 3 second.	→ BOTTOM CAN
press-ring (pr1) Std. time = 4 second.		→ RING CAN

Table 8 Rectangular can line data.

M 1	M2	Part of rectangular can
press-top Std. time = 3 second.	→ sealing-top Std. time = 5 second.	→ TOP CAN
press-bottom Std. time = 4 second.	→ sealing-bottom Std. time = 5 second.	→ BOTTOM CAN
press- handle Std. time = 6 second.		→ RING CAN

2) Let's assume a list of jobs in a month which consisted of different product orders and quantity and different due dates to test different dispatching rules.

Table 9 Example data from sale department and for calculation dispatching rules

| Job | Class | Q'ty | Max{M1 + M2} | Total | Due date | |
				Prod. Time	Date	Mth.
A_0	A_1	A_2	A_3	A_4	A_5	A_6
1	5	5	9	45	15	1
2	5	10	9	90	25	1
3	2	15	7	105	20	1
4	5	20	9	180	20	1
5	5	25	9	225	14	1
6	2	20	7	140	15	1
7	2	10	7	70	8	1
8	5	5	9	45	8	1
9	2	20	7	140	24	1
10	5	10	9	90	12	1

Testing the data from the above table by using different dispatching rules as follows;

1. First Come First Serve (FCFS): Considering queue of job in column A_0 by scheduling list of jobs in the order of job come first, done first. Thus, using this rule the job in table 9 will be scheduled for round can line as (3, 6, 7, 9) and rectangular can line is (1, 2, 4, 5, 8, 10)

2   Earliest Due Date (EDD): Considering due date of job in column A_5 and A_6. The earliest due date rule orders the sequence of jobs to be done from the job with the earliest due date to the job with the latest due date. Let $d_{[i]}$ denote the due date of the i th job in the ordered sequences job such that the following in equality holds,

$$d_{[i]} \leq d_{[2]} \leq \ldots \leq d_{[n]}$$

Thus, using this rule the round can job in previous example can be scheduled as (7, 6, 3, 9) and rectangular can line is (8, 10, 5, 1, 4, 2). If the condition of early due date is equal, chose to the first priority the maximum of sum production time.

3. Shortest Processing Time Rules (SPT): Considering production time of job in column A_4 by scheduling list of jobs in the order of increasing processing time. Whenever a machine is freed, Let $t_{[i]}$ denote the processing time of the i th job in the order of the shortest job available at the time will begin processing that the following in equality holds,

$$t_{[i]} \leq t_{[2]} \leq \ldots \leq t_{[n]}$$

Thus, using this rule the job of round can line in previous example can be scheduled as (7, 3, 6, 9) or (7, 3, 9, 6) and rectangular can line is(8, 1, 10, 2, 4, 5), (8, 1, 2, 10, 4, 5), (1, 8, 10, 2, 4, 5) or (1, 8, 2, 10, 4, 5)

In the condition where sum of production time is equal, chose early due date (minimum of A_5 and A_6) to be first priority. Thus, this example can be scheduled round can line as (7, 3, 6, 9) and rectangular can line as (8, 1, 10, 2, 4, 5)

4. Longest Processing Time Rules (LPT): Consider production time of job in column A_5 by scheduling list of jobs in the order of decreasing processing time. Whenever a machine is freed, the largest job ready at the time will begin processing. Thus, using this rule the job in previous example can be scheduled round can jobs as (6, 9, 7, 3) or (9, 6, 7, 3) and rectangular can line is (5, 4 , 10 , 2 , 8, 1) , (5, 4 , 10 , 2 , 1, 8), (5, 4 , 2 , 10 , 8, 1) or (5, 4 , 2 , 10 , 1, 8)

In the condition where sum of the production time is equal, choose early due date (minimum of A_5 and A_6) to be first priority. Thus, this example, round can line can be scheduled as (6, 9, 3, 7) and rectangular can line as (5, 4, 10, 2, 8, 1).

It can be seen from the example above that different dispatching rules yield different job assignments and different completion time. In this test data the best dispatching rule is SPT as summarized in table 10.

Table 10 Conclusion of job sequencing by using dispatching rules.

	Dispatching Rules	Job Sequencing Order
	Line : Round can	
1)	FIFO	3 → 6→ 7→ 9
2)	EDD	7→ 6→ 3→ 9
3)	SPT	7→ 3→ 6→ 9
4)	LPT	6→ 9→ 3→ 7
	Line : Rectangular can	
5)	FIFO	1→ 2→ 4→ 5→ 8→ 10
6)	EDD	8→ 10→ 5→ 1→ 4→ 2
7)	SPT	8→ 1→ 10→ 2→ 4→ 5
8)	LPT	5→ 4→ 10→ 2→ 8→ 1

Table 11 The comparison C_{max} in phase I by using dispatching rules

	C_{max}

Job no. (Ao)	FCFS	EDD	SPT	LPT
1	45	310	70	475
2	110	460	180	425
3	105	225	145	265
4	240	410	300	325
5	365	285	450	225
6	200	180	240	140
7	230	70	70	295
8	390	45	45	450
9	320	320	320	220
10	450	110	130	375
Total: Round can	855	795	775	920
Total: Rectangular can	1600	1620	1175	2275

4. PhaseII Workforce scheduling

The second phase of the problem is to assign workers to machines by using a set of heuristic rules in order to minimize the maximum completion time of all tasks.

In addition, the following assumptions are made:

1. There is a certain ratio of skill workers among the work force.

2. If the worker skill does not match with the machine, there is a penalty on the completion time. No penalty is applied when the skill of operator matches with the machine.

3. There are equal numbers of workers to the number of machines.

Heuristics rules for workforce scheduling

1. Skill levels of workforce

In the situation where manual works involve the skill of individual operator, skill levels will have a significant impact on the productivity of the production line. From the study of Piece Rate and Learning[1] found that experienced workers can have an increase in output ranging from 15% - 123%. The assumption that all workers have the same skill level is certainly a misconception. Phase II will look into the effect of different skill levels of workforce on the scheduling problems. The assumption used in the study is that workers have differentiation in skills, in this case, single or multi-skill. The study will investigate the case of different ratio of multi-skill workers in the workforce ranging from 0% to 100%. The ratio of multi-skill to single-skill are in 5 different sets ranging from 0-100, 20-80, 50-50, 80-20 and 100-0.

2. Assignment rules.

There are three methods for assigning workers to machines namely;
-   Assigning single skill workers first (S)
-   Assigning multi-skill workers first (M)
-   Random allocation. (R)

3. Machine priority rules

Since the machines in each stage are not of equal number and parts do not go through the same numbers of process, there is an interest to see if machine priority may have the effects on the completion time. The heuristic rules for machine priority setting are:

-   Priority to machines with highest processing time first (processing),
-   Priority to sequential machines first(continuous), and

- Priority to machines with higher number of available machines first(maximum).

All heuristic rules in Phase II have to combine with those in Phase I .

To give some example of how the different heuristic rules operate in phase II, let's take the previous case example from Phase I and apply workforce assignment with different skills. The workforce required in this case is 12. If the workforce consisted of 20% multi-skill and 80% are single skill, this means there are 3 multi-skill workers and 9 single skill workers.

Table 12 Identify skill to the worker

Skill number	Number of worker	Press	Seal
1	4	✓	
2	5		✓
3	3	✓	✓

Testing of assignment rules:

1. Random Allocation

This rule is to assign workers to jobs and machines in random order regardless of their skill levels. Neither does it is consider whether the skill of worker matches with the machine. If the worker skill does not match with the machine, there is a penalty on the completion time. No penalty is applied when the skill of operator matches with the machine.

Multiple and Single skill workers   **Machines**

Figure13 Random Allocation

2. Allocate Workers with Multi-skill First

This rule is to assign multi-skill workers to machines first until no multi-skill workers left before assigning single-skill workers into machines. There is also penalty for unmatched skills.

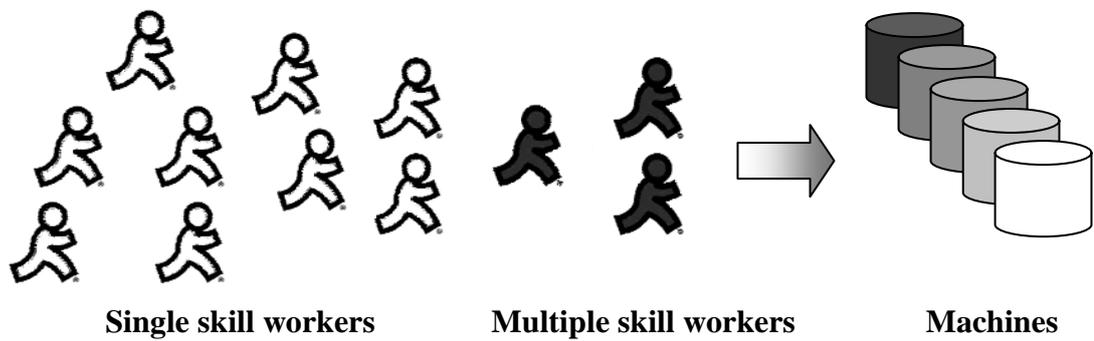**Single skill workers**   **Multiple skill workers**   **Machines**

Figure14 Allocate Workers with Multi-skill First

3. Allocate Workers with Single-skill First

This rule allows workers with single-skill to select the machines first until no single-skill worker left and then select multi-skill workers into machines. Penalty rate is applied.

Multiple skill workers   **Single skill workers**   **Machines**

Figure15 Allocate Workers with Single-skill First

Testing of machine priority rules:

There are 3 types of machine priority rule; maximum processing time first, sequential machines first, and higher number of available machines first.

1. Maximum processing time

Set priority of machine by assigning the maximum processing time first. This method can prevent the worker who does not have skill matching run into the high processing time machines and eventually increase the overall completion time.
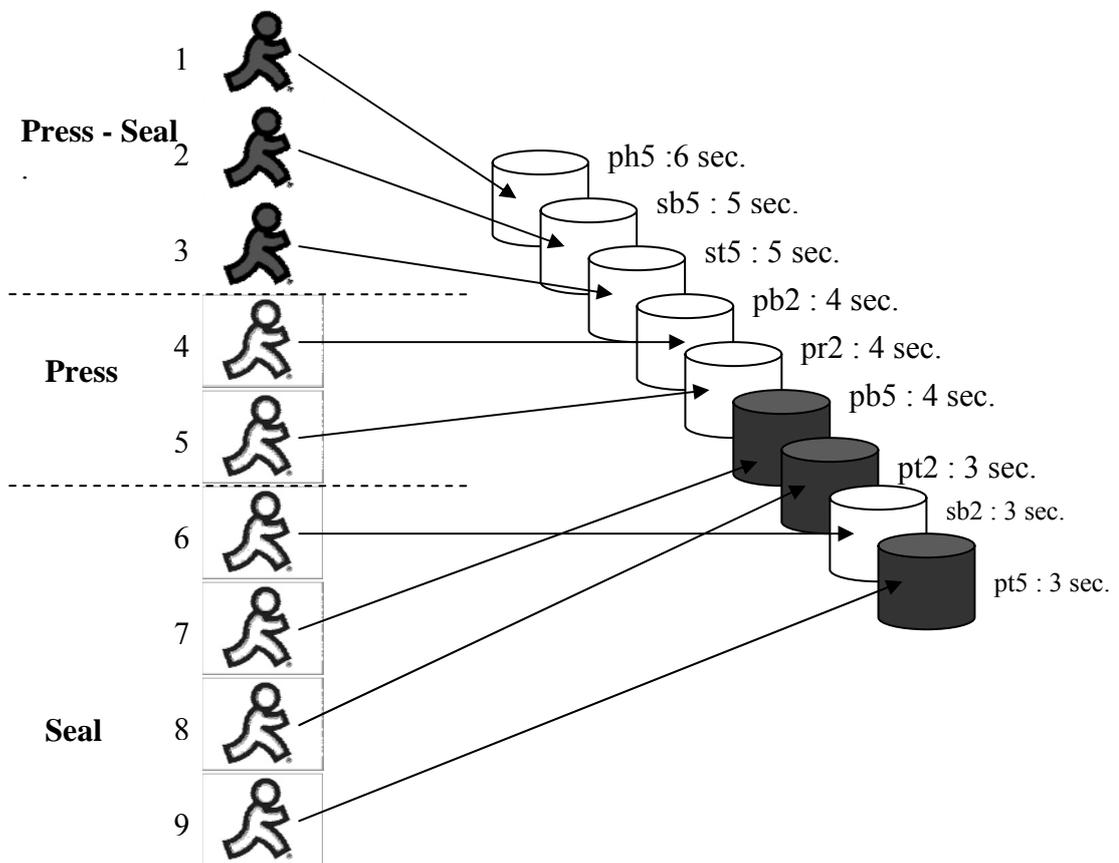

Figure 16   Maximum processing time

From example the data come from table 7,8 and 12, sequencing the worker by using multiple skill first and then worker select the machine by order of decreasing processing time machine. In this case 3 workers from the last worker have to do the job which does not match his skill.

2. Sequential machines

Set priority of machine by assigning workers to sequential machines first. This method can prevent the single-skill workers run into the long process machines and unmatched skill which will affect the overall completion time.
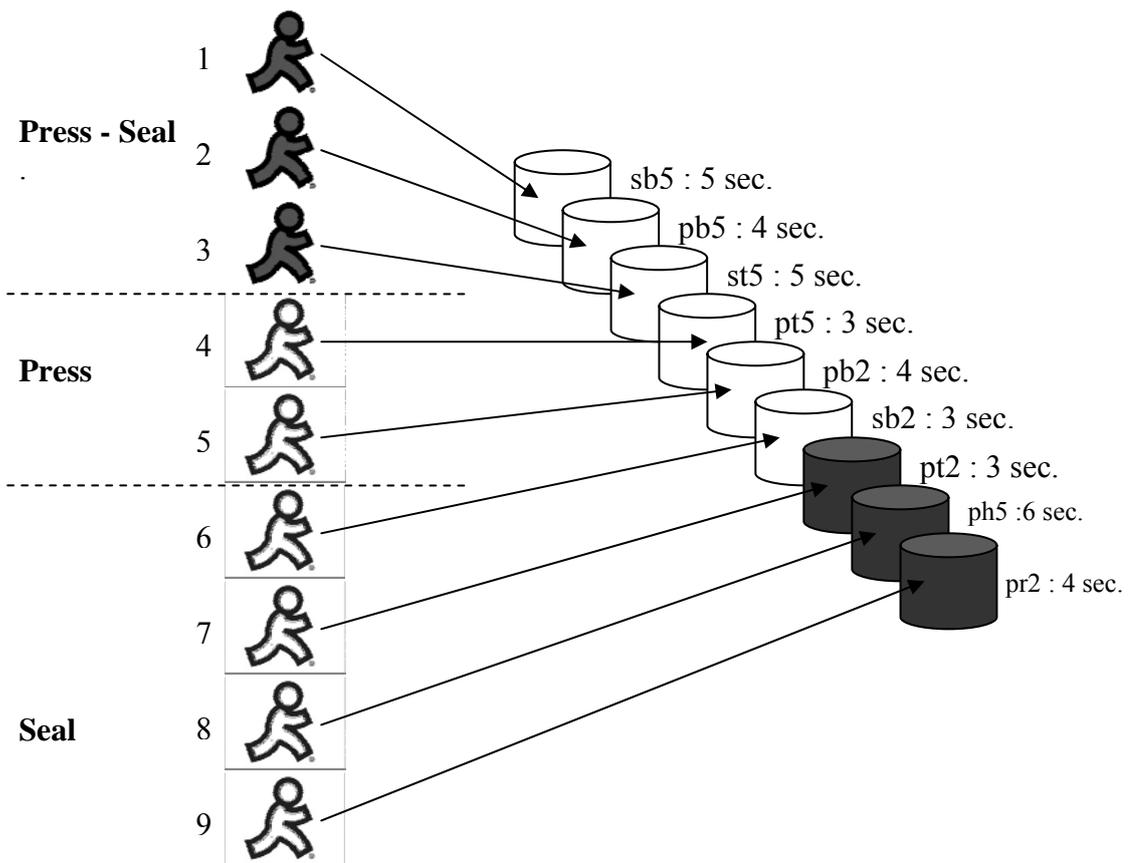

Figure17   Sequential machines

Following the same example from table7,8 and 12, after sequencing the worker by using multiple skill first, then set priority to sequential machines. The result in this case will leave the last 3 workers to work on press top M1 with processing time of 3 sec, press handle M2 with processing time of 6 sec and press ring M1 with processing time of 4 sec.

3. Higher number of available machines

Set priorities of machine to higher number of machines first. This method can prevent the company from having more unmatched jobs towards the end.
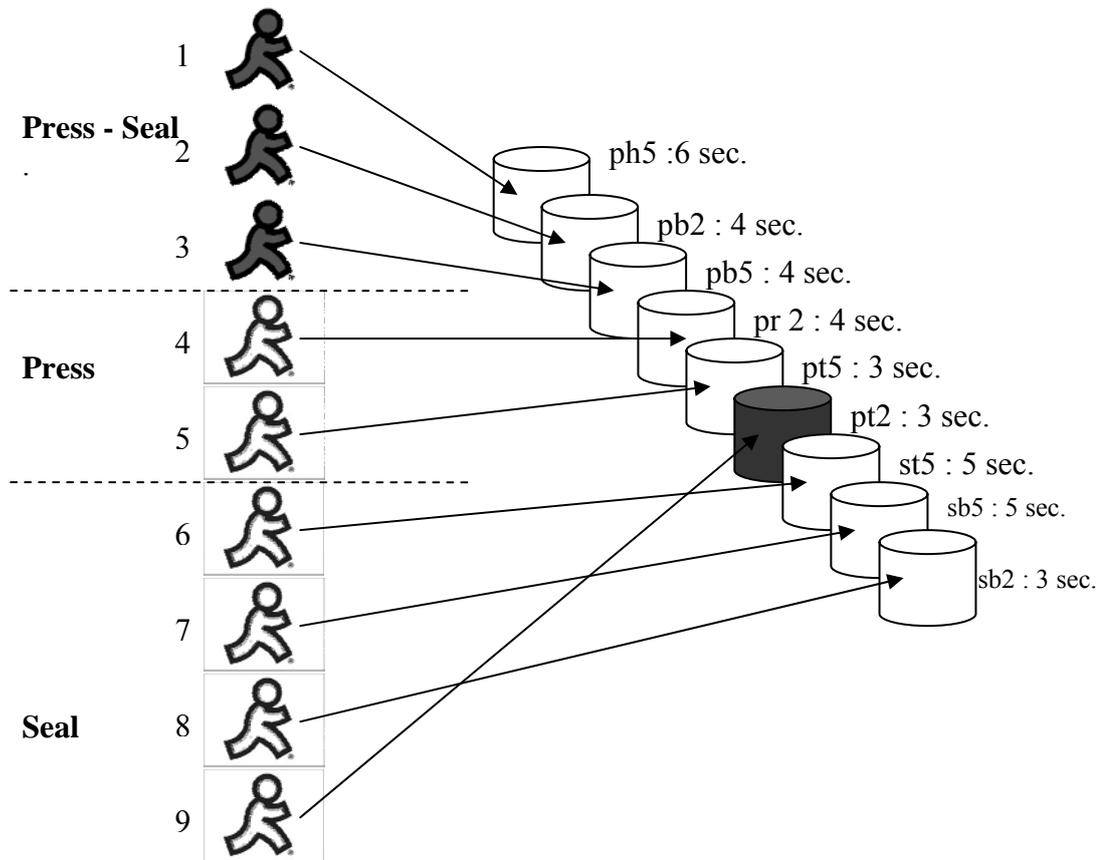

Figure18   Higher number of available machines

Using same data from table7,8 and 12, sequencing the worker by using multiple skill first and then worker select the machine from group with higher number of machines. The result in this case is worker number 9 have to do the unmatched-skill job which is Press top M1 with processing time of 3 sec.

Table 13 The comparison $C_{max,SPT}$ by multi-skill First at 20:80 arrangement rule

Job no.	C_{max}		
	Maximum processing time	Sequential machines	Higher number of available machines
1	450	600	315
2	130	120	90
3	150	200	145
4	340	360	300
5	565	660	525
6	270	360	240
7	60	80	70
8	420	560	295
9	390	520	320
10	510	680	370
Total: Round can	870	1160	775
Total: Rectangular can	2415	2980	1895

Thus, it can be concluded that the case of multi-skill first at 20:80 arrangement rule that C_{max} from higher number of available machines is better than other machine priority rules.

Penalty rate

There is a penalty for all the unmatched skill allocated. The penalty rate is the increase in the processing time on the assigned unmatched job. Three values of penalty rates are used in order to see the effects on the results.

- Standard time is increased by 100 %
- Standard time is increased by 50 %
- Standard time is increased by 25 %

5. <u>Solving the heuristic algorithm</u>

In order to solve this scheduling problem, Visual Basic 6 was chosen as the application tool to develop a program for solving the problem.

Step I :
Job Sequencing

Data Input
Order : Order No., Item Code, Oty.,Due dute
MC: MC name, MC Function,Qty,Std.Time
Worker : Skill level (multi skill = 0,20,50,80,100) ,
Skill (Press.seal)

No

Dispatching rules for job scheduling

Dispatching rules
i : Method (1,2,3,4)

1.FIFO order arrival time
$j_1,j_2,\ldots,j_n$
2. EDD order the nearest due date
$d_1 \le d_2 \le \ldots d_{\{n\}}$
3. SPT order increase processing time
$t_1 \le t_2 \le \ldots t_{\{n\}}$
4. LPT order decrease processing time
$t_1 \ge t_2 \ge \ldots t_{\{n\}}$

$C_{max,1} = Min\ [C_{max\,,\,i}\,]$

Yes

Scheduling I

Result: Best dispatching rule , jobs to machines

Step II : Workforce scheduling

Workforce scheduling

Assignment rules
j: Method (1,2,3)

1. Single skill workers first
2. Multi-skill workers first
3. Random allocation.

Matching
Skill workers = MC function

Yes

No

Machine priority rules
k: Method (1,2,3)

1. Maximum processing time first
2. Sequential machines first
3. Higher number of available machines first.

Processing time =
Std. time * 1

Processing time =
1) Std. time * 1.25
2) Std. time * 1.50
3) Std. time * 2

$C_{max} = Min\ [C_{max\,2,jk}]$

C_{max} and Scheduling II

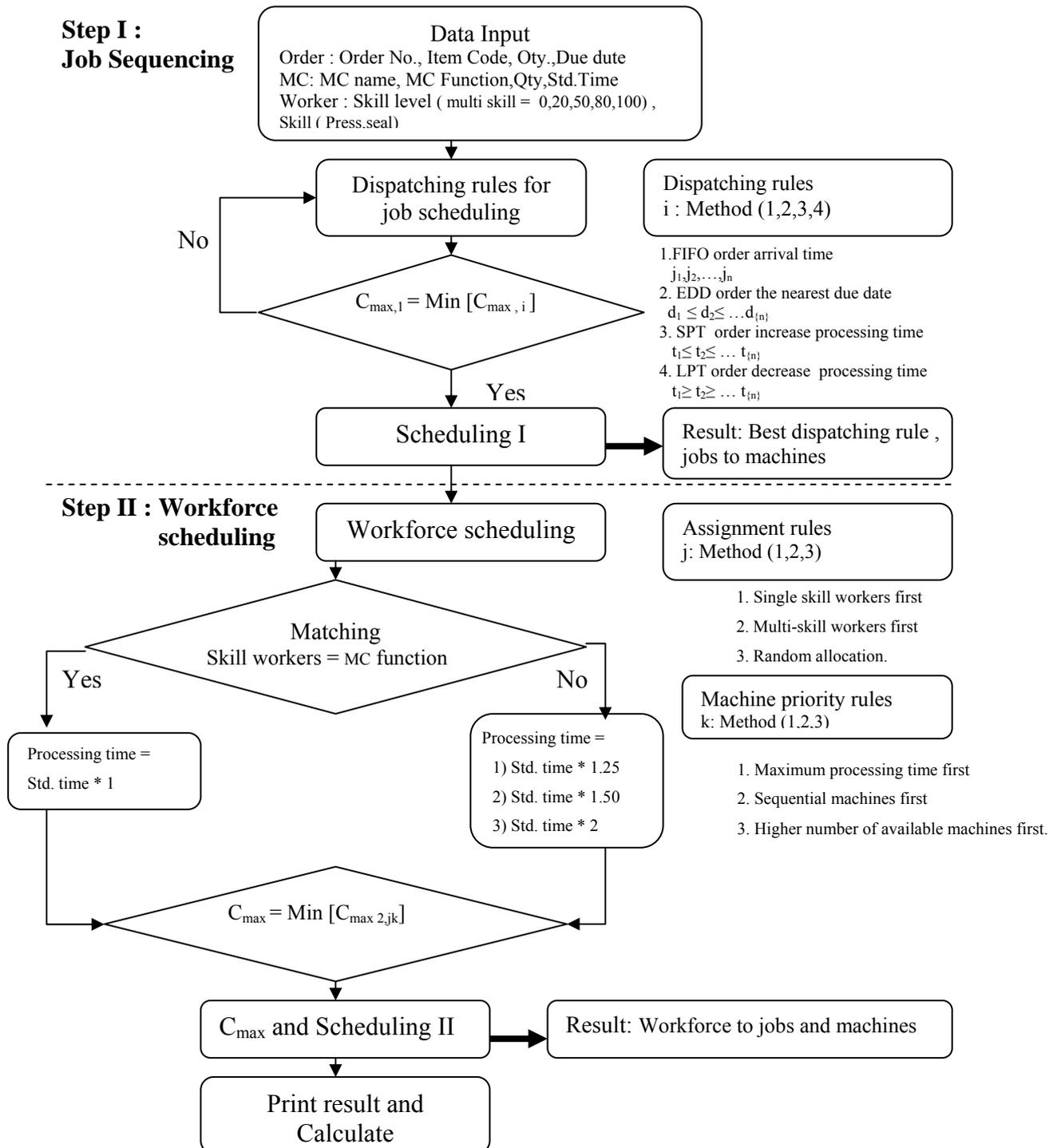Result: Workforce to jobs and machines

Print result and Calculate

Figure 19 Heuristic Flow Chart

The program has been tested by using a small set of data as shown in the earlier example for its reliability. Finally the full data set has been used for the final testing and conclusion.