CHAPTER 5

The proposed ways for shop floor productivity improvement

Shop floor is the focal point of asset management. Not only does the responsibility for plant equipment rest there, but also the prime mover/inhibitor of company cash flow. The manner in which a product is moved and controlled determines the level of work-in-process inventory and, therefore the rate at which money turn over. Labor, material, and overhead, which make up cost of goods sold, typically represent 50 - 80 % of a company's sale. Therefore, maximization of total factory throughput and the minimization of those costs, while optimizing customer service, makes good business sense. We can increase the throughput by reducing *manufacturing lead time* (Figure 5.1).

Manufacturing lead time is the sum of the lead times for every operation required to make the product and operation lead time consists of queue time before processing, setup time, run time, wait time after processing, and move time (as displayed by Figure 5.2). Experience has shown that queue and wait time account for 90 % or more of operation lead time in discrete batch manufacturing. The variation of size of the queues varies the level of work-in-process inventory and directly affects the cycle time of a particular job order.

Each workstation should be scheduled so that backlogs are

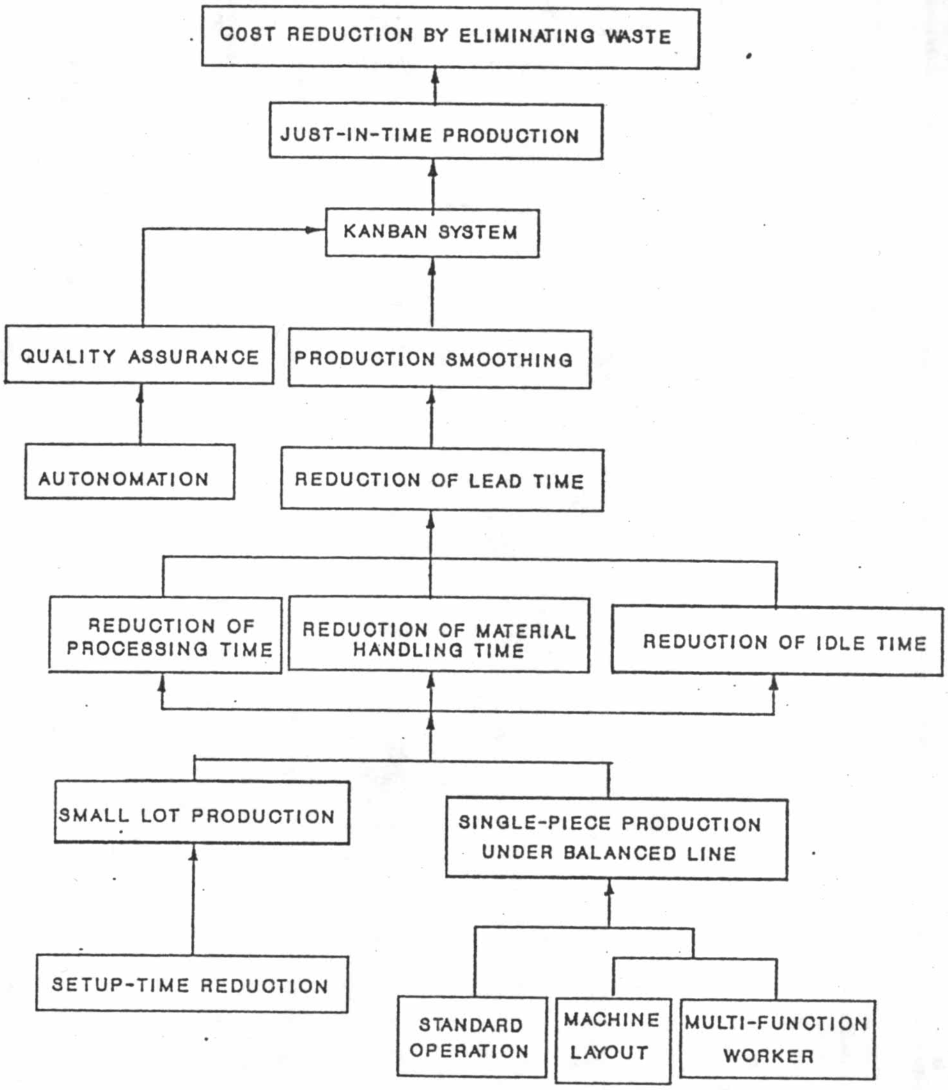


Figure 5.1. The way to reduces manufacturing lead time.

controlled to the optimal level. If the level could not controlled then the queues grow, it cause the inflation of work-in-process inventory, an increasing of lead time, and delivery dates may be extended. Conversely, if the queues are shrinked, downtime may occur at workstations and the productivity may be dropped. Therefore, it is necessary to control actual queues to an optimal level as a means of simultaneously achieving high productivity, performance to schedule, and minimum inventory investment.

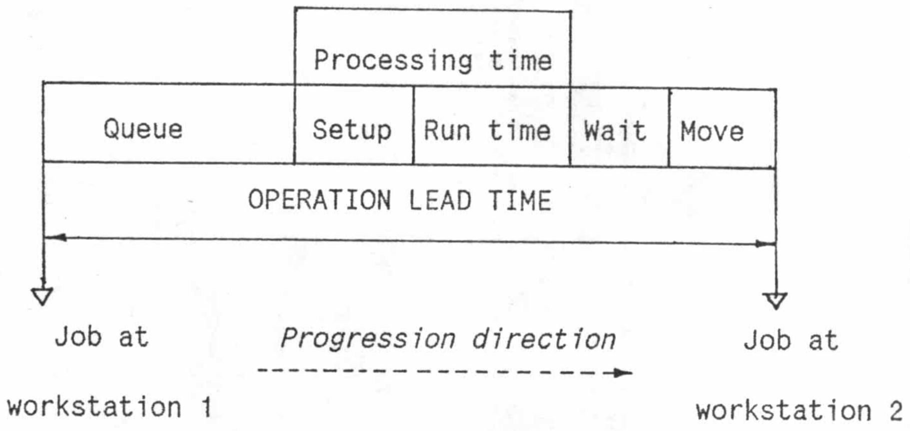


Figure 5.2. Operation lead time.

This chapter propose ways to improve the shop floor for higher productivity. The proposed methods of the section described below require little additional cost and can be done immediately. Examples of changing from old to new methods include: the reduction of distance traveled, material handling time, setup time, and operation lead time.

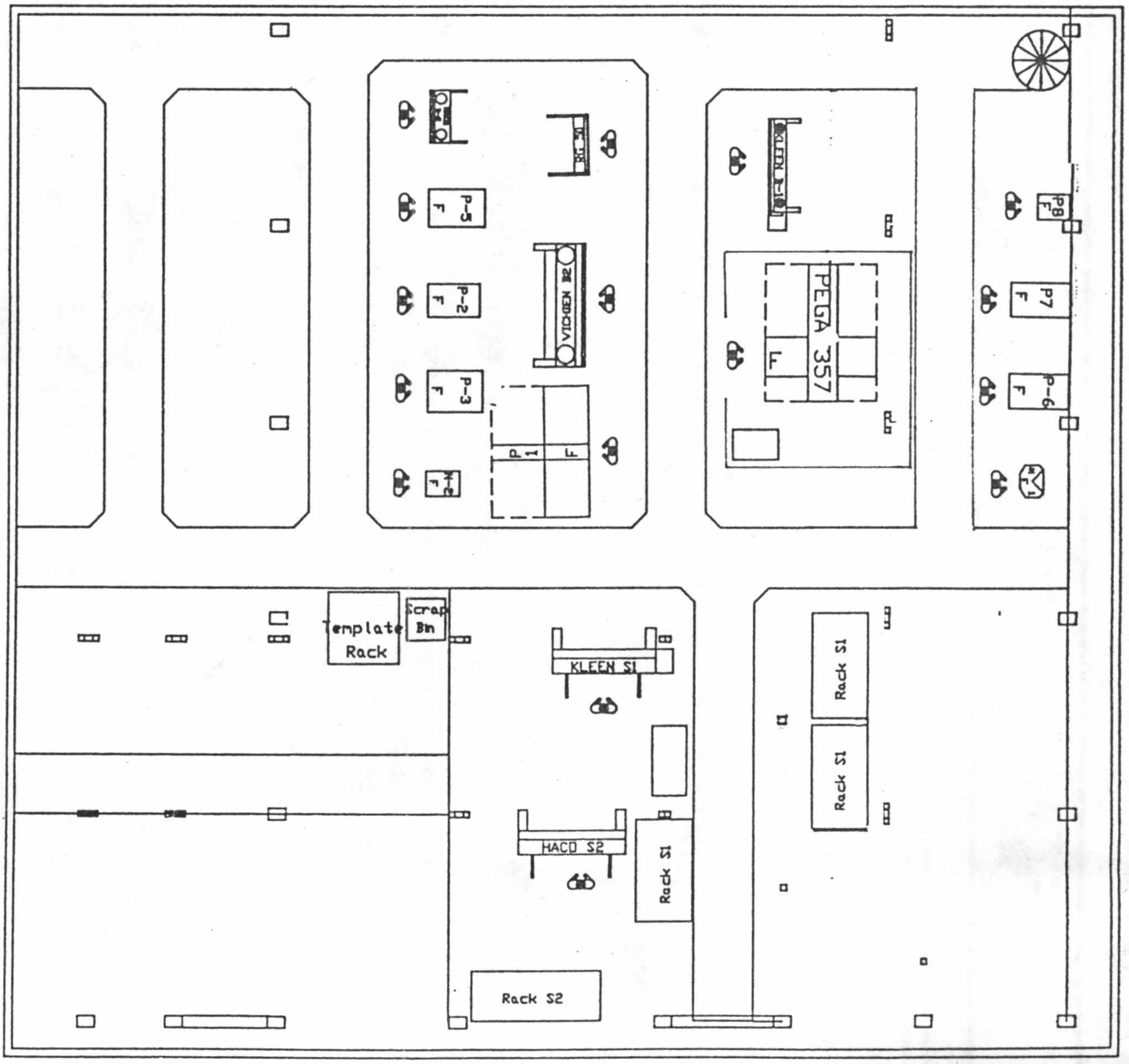


Figure 5.3. Proposed layout for fabrication section.

Shop floor layout

workstations and facilities for the present layout make long material handling paths. Some machines including racks and scrap bins should be relocated for shorter path movement. The present and proposed layouts are, respectively, shown in Figure 3.10 and 5.3. In Figure 5.3, one can see that shearing machines are relocated closer to another types of machines.

Distances from shearing machines to another machines of an existing and proposed layouts are represented in form of *From-To chart* as shown by Figure 5.4(a) and 5.4(b) respectively.

To

Distance in metre

From	S-1	S-2	P-1	P-2	P-3	P-5	P-6	P-7	P-9	B-1	B-2	B-3	B-4
S-1		11.8	10.0	19.0	16.8	21.2	9.0	11.2	9.0	14.0	14.0	23.0	18.0
S-2			19.2	28.3	26.3	30.3	10.0	12.2	18.3	23.3	23.2	32.5	27.2
P-1				16.2	14.0	18.4	14.7	16.9	3.0	10.3	2.2	15.0	8.0
P-2					2.2	4.4	24.3	26.5	15.0	17.6	20.6	4.4	13.2
P-3						4.4	22.8	25.0	12.0	19.8	18.4	6.6	16.2
P-5							27.2	29.4	17.0	15.4	18.4	2.2	11.0
P-6								2.2	12.0	22.8	19.1	29.4	22.8
P-7									11.0	25.0	21.3	31.6	25.0
P-9										5.0	3.5	12.0	6.5
B-1											5.0	3.5	12.0
B-2												5.0	10.0
B-3													8.0
B-4													

Figure 5.4(a). From-to chart for present layout.

Figure 5.5 shows data of the frequency of material handling between machine for a period of 10 observed-working days. Combining the data in Figure 5.4 (both) and 5.5, we then obtain the material handling distance traveled (as displayed by Figure 5.6(a) and 5.6(b)). About 50 metre average distance traveled per day is reduced if the layout is changed.

The reduction of travelling distance in *flow shop* may not always be affected the increasing of productivity because cycle times are not reduced. However, flow time of *job shop* may be decreased and productivity may be increased when distance traveled is reduced.

To

Distance in metre

From

	S-1	S-2	P-1	P-2	P-3	P-5	P-6	P-7	P-9	B-1	B-2	B-3	B-4
S-1		10.8	4.2	11.1	8.9	13.3	3.0	5.2	8.0	14.0	7.0	15.5	14.8
S-2			10.0	16.6	14.4	18.8	23.3	26.5	12.0	24.2	17.6	21.0	25.6
P-1				16.2	14.0	18.4	14.7	16.9	3.0	10.3	2.2	15.0	8.0
P-2					2.2	4.4	24.3	26.5	15.0	17.6	20.6	4.4	13.2
P-3						4.4	22.8	25.0	12.0	19.8	18.4	6.6	16.2
P-5							27.2	29.4	17.0	15.4	18.4	2.2	11.0
P-6								2.2	12.0	22.8	19.1	29.4	22.8
P-7									11.0	25.0	21.3	31.6	25.0
P-9										5.0	3.5	12.0	6.5
B-1											5.0	3.5	12.0
B-2												5.0	10.0
B-3													8.0
B-4													

Figure 5.4(b). From-to chart for proposed layout.

To

From	S-1	S-2	P-1	P-2	P-3	P-5	P-6	P-7	P-9	B-1	B-2	B-3	B-4
S-1		4	1	13	0	13	8	6	30	1	1	1	1
S-2			0	7	8	24	10	14	2	0	1	0	3
P-1				3	0	0	1	2	0	1	0	1	1
P-2					3	0	0	0	0	4	2	3	2
P-3						2	0	1	1	4	0	2	0
P-5							0	1	0	20	1	3	11
P-6								0	0	2	1	8	4
P-7									2	6	2	3	1
P-9										8	7	1	12
B-1											8	3	15
B-2												1	3
B-3													1
B-4													

Figure 5.5. The frequency of material handling .

To

From	S-1	S-2	P-1	P-2	P-3	P-5	P-6	P-7	P-9	B-1	B-2	B-3	B-4	TOTAL
S-1		47.2	10.0	247.0	0.0	275.6	72.0	67.2	270.0	14.0	14.0	23.0	18.0	1058.0
S-2			0.0	198.1	210.4	727.2	100.0	171.2	36.6	0.0	23.2	0.0	81.6	1548.3
P-1				48.6	0.0	0.0	14.7	33.8	0.0	10.3	0.0	15.0	8.0	130.4
P-2					6.6	0.0	0.0	0.0	0.0	70.4	41.2	13.2	26.4	157.8
P-3						8.8	0.0	25.0	12.0	79.2	0.0	13.2	0.0	138.2
P-5							0.0	29.4	0.0	308.0	18.4	6.6	121.0	483.4
P-6								0.0	0.0	45.6	19.1	235.2	91.2	391.1
P-7									22.0	150.0	42.6	94.8	25.0	334.4
P-9										40.0	24.5	12.0	78.0	154.5
B-1											40.0	10.5	180.0	230.5
B-2												8.0	0.0	8.0
B-3													8.0	8.0
B-4														
TOTAL	47.2	10.0	493.7	217.0	1011.6	186.7	326.6	340.6	717.5	223.0	431.5	637.2		4634.6

Figure 5.6(a). Material handling distance traveled (for ten days observation) for present layout.

To

From	S-1	S-2	P-1	P-2	P-3	P-5	P-6	P-7	P-9	B-1	B-2	B-3	B-4	TOTAL
S-1		43.2	4.2	144.3	0.0	172.9	24.0	31.2	240.0	14.0	7.0	15.5	14.8	711.1
S-2			0.0	116.2	115.2	451.2	233.0	371.0	24.0	0.0	17.6	0.0	76.8	1405.0
P-1				48.6	0.0	0.0	14.7	33.8	0.0	10.3	0.0	15.0	8.0	130.4
P-2					6.6	0.0	0.0	0.0	0.0	70.4	41.2	13.2	26.4	157.8
P-3						8.8	0.0	25.0	12.0	79.2	0.0	13.2	0.0	138.2
P-5							0.0	29.4	0.0	308.0	18.4	6.6	121.0	483.4
P-6								0.0	0.0	45.6	19.1	235.2	91.2	391.1
P-7									22.0	150.0	42.6	94.8	25.0	334.4
P-9										40.0	24.5	12.0	78.0	154.5
B-1											40.0	10.5	180.0	230.5
B-2												5.0	30.0	35.0
B-3													8.0	8.0
B-4														
TOTAL		43.2	4.2	309.1	121.8	632.9	271.7	490.4	298.0	717.5	210.4	421.0	659.2	4179.4

Figure 5.6(b). Material handling distance traveled (for ten days observation) for proposed layout.

Converting internal setup to external setup

Manual punch press machines normally have ten to fifteen minutes for setup activities. All setup activities for present method are internal setup. Internal setup means that operator takes actions while the machine is stopping. In fact, at least 60 to 70 % of setup operations for these machines can be done while the machine is running.

Monden (1987) stated that in order to shorten the setup time, it is important to neatly prepare in advance the necessary jigs, tools, the next die and materials and remove the detached die and jigs after the new die is settled and the machine begins to operate. This phase of setup actions is called the *external setup.*

At manual punch press machine workstations, for the present method, only one worker is responsible to produce workpieces which are moved from a prevoius workstation by himself until complete without assistance. Operations for this method are as follow :

a) Walk to upstream workstation;

b) Move materials to the manual punch press machine;

c) Remove old die;

d) Prepare new die;

e) Install die and setup machine;

f) Manipulate material on machine;

g) Remove and transfer materials from the workstation to the next station.

By proposed method, while machine is running, external setup actions are done by a second worker simultaneously. The first worker is only responsible on operation *c*, *e* and *f*. The remainder is done by the second worker.

Present method spends 15 minutes for setup activities while times used for internal setup is normally 5 minutes. Therefore, if the setup activities are converted to external setup, the time for setup actions will then be reduced to 5 minutes.

If a_i is represented to run time (minute/plate) for *i*th batch;

n_i is the number of plates for *i*th batch;

N_i is the number of setup for *i*th batch;

L is the number of batches production per day;.

$$\text{Then processing time} = \sum^{L} N_i\{ \textit{setup time} + (a_i)(n_i)\}$$

For present method :

$$\text{processing time} = \sum^{L} N_i\{\ 15 + (a_i)(n_i)\} \quad \text{minutes}$$

For proposed method :

$$\text{processing time} = \sum^{L} N_i\{\ 5 + (a_i)(n_i)\} \quad \text{minutes}$$

If $L = 1$ (or produce 1 batch), $a = 0.1$ minute/plate, and $n =$ 99 plates.

processing time for present method

= 15 + (0.1)(99)

= 24.9 minutes

processing time for proposed method

= 5 + (0.1)(99)

= 14.9 minutes

If the quantity in lot is not changed, the operation lead time for proposed method is less than that of present method for 10 minutes per one setup actions.

Machine numbers P-2, P-5, P-6, and P-7 are the same type of manual punch press machines, where the internal setup can be converted to external setup, they have an average of six production batches per day. If each batch needs two setups then the proposed method can reduce operation times as follows :

Time reduced = (reduced setup time per 1 setup) x (avg. no. of setup per batch) x (avg. no. of batch) x (no.of machine)

= (10)(2)(6)(4)

= 480 minutes

From Table 5.1 we can compute an average production rate of four manual punch press machine (P-2,P-5,P-6 and P-7), the average production rate is (716+466+590+481)/4 = 560 pieces per 8 working hours.

For proposed method if the lot size is changed to 33 plates (insteads of 99), then :

processing time = 5 + (0.1)(33) = 8.3 minutes

Notice that if multiply proposed setup time by 3, it gives the value equals 15 which is equal to setup time of present method. If the processing time for proposed method is multiplied by 3, it gives the value equals 24.9 which is equal to setup time of present method. This means that the proposed method, when setup time is reduced from 15 minutes to 5 minutes, can reduces the lot size by 3 times. Smaller lot sizes will certainly have shorter operation lead times than larger lot sizes. The sheet-metal components will sent to assembly sections quicker.

Multi-operations by multi punch press machines

Most components which are passed through punching operations normally need more than one punching step. For present method, sheet-metal components are manipulated on one punch press machine. Many manual punch press machines complete their jobs while the downstream machines (either notching or press brake machines) are still running, creating an unavoidable increasing of delays and work-in-process inventories.

For proposed method, when the first step from the first manual punch press machine is completed, the workpiece is transferred to the second punch press machine to immediately punch in the second step and transferred to the third machine for third step punching. The finished parts of this method only come out from the last punch press machine. By this method, the use of hand trucks and shop floor spaces for stacking work-in-processand operation lead time are reduced.

If a is represented to run time (minutes/plate);

n is represented to number of plates;

N is represented to number of setup actions.

then the processing time for present method

$$= N\,(\ \textit{setup time} + (a)(n)\ ) \qquad \text{minutes} \qquad \text{(a)}$$

and for proposed method

$$= \textit{setup time} + a\,(\ n + N - 1\ ) \qquad \text{minutes} \qquad \text{(b)}$$

for example, If a = 0.1 min/plate , n = 100 plates, and N = 4

processing time for present method = 4(5 + (0.1)(100))

= 60.0 minutes

(It was assumed that setup time is already converted into *internal setup*)

processing time for proposed method = 5 + 0.1(100 + 4 - 1)

= 15.3 minutes

therefore, the different processing time = (a) - (b) minutes

for this example the processing time is reduced

= 60.0 - 15.3 minutes

= 34.7 minutes

Production reporting

In the past, the fabrication section never recorded the production data. Therefore no historical data for capacity, actual load by time period, and performance data (e.g., efficiency, percent of work on schedule, average input/output) is unknowned. This finally causes work management difficulty and difficulty in improving and controlling the shop floor productivity.

The production activities that employees must report are those dealing with job performance. Material movement, job/machine setup, part and assembly production, work interruptions, scrap or rework, and nonproductive activities are some of types of reporting required. As production reports are completed, historical information can be developed and organized to analyze the following :

Actual vs. standard time (for efficiency calculations).

Labor reporting (to identify areas needing additional supervisor assistance or training).

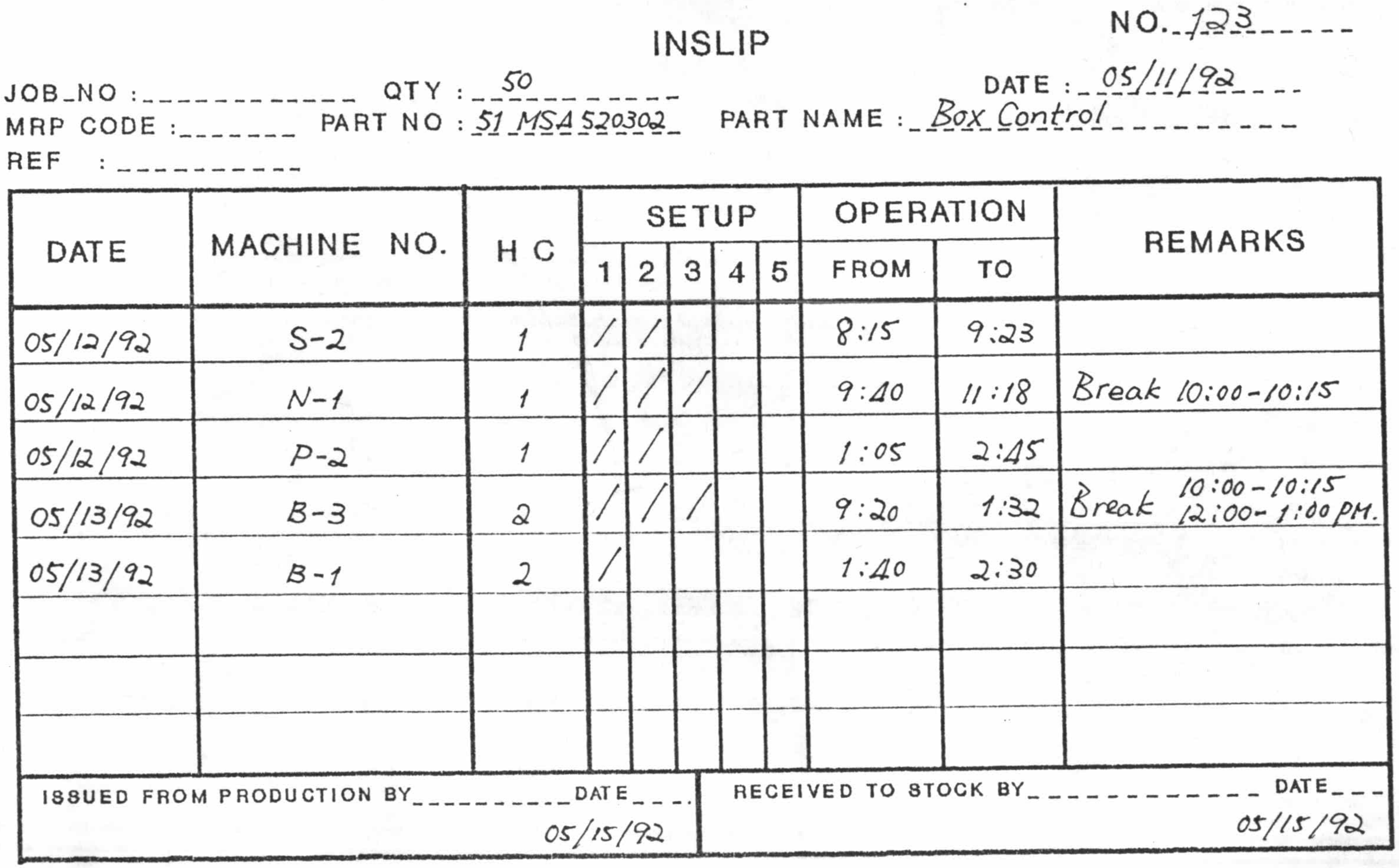
Actual vs. standard time to manufacture (to analyze lead times).

To establishes the production and engineering data base, it is necessary to report shop floor activities using the *Inslip sheet.* The following are advantages of this report:

1. Can compute operation lead times for each components. The times are also needed for accounting and planning departments to evaluate production costs and delivery dates.

2. They shows actual operation sequences (or *process routings*).

3. Can compute actual machine capacity and utilization.



NO. 123

INSLIP

JOB_NO :

QTY : 50

DATE : 05/11/92

MRP CODE :

PART NO : 51 MSA 520302

PART NAME : Box Control

REF :

DATE	MACHINE NO.	H C	SETUP					OPERATION		REMARKS
			1	2	3	4	5	FROM	TO	
05/12/92	S-2	1	/	/				8:15	9:23	
05/12/92	N-1	1	/	/	/			9:40	11:18	Break 10:00-10:15
05/12/92	P-2	1	/	/				1:05	2:45	
05/13/92	B-3	2	/	/	/			9:20	1:32	Break 10:00-10:15 12:00-1:00 PM.
05/13/92	B-1	2	/					1:40	2:30	

ISSUED FROM PRODUCTION BY DATE 05/15/92

RECEIVED TO STOCK BY DATE 05/15/92

Figure 5.7. Inslip sheet.

4. Workers at workstations feel less threatened than when using specific production sheets at specific machines (because these production sheets are passed through to end of operation sequence and one sheet is recorded by at least 3 workstations' leaders).

The blanked inslip sheets which are specified the details such as part name, part number and quantity required are issued by planning department to production department. When the inslip are sent to shop floor, workers at each work station where the part are passed through are responsible to record production data on these sheets.

Figure 5.7 shows a sample of inslip.

Throughput index and productivity

The performance of a shop can be evaluated in many different ways, and the relevant criteria differ from shop to shop. The most commonly used ones are the throughput rate, the flow time, the level of work-in-process, and the due-date performance. Han and McGinnis (1989) developed the shop operating characteristics (SOC) curve supporting both simulation studies and actual shop operations by showing in one view the relationship between the throughput rate, the flow time, and the work-in-process inventory. The curve is used to compare the performance of alternative control rules or alternative shop configurations.

The following is the notation used for establishing formalae of throughput rate, flow time and work-in-process :

i workstation index, $i = 1,2,3,\ldots,m$;

m number of workstations in the shop;

j job index;

a_{ij} processing time of job j at workstation i;

t length of the observation period;

J_t set of jobs completed during time period t; and

n_t cardinality of J_t.

a) Throughput index, θ

If the production process has been observed for a time period of length t, the throughput index θ_t is definded as

$$t = v_t / \bar{a}_t$$

where v_t and a_t are

$$v_t = t / n_t$$

and

$$\bar{a}_t = \sum_{j \in J_t} \sum_{i} a_{ij} / n_t \, m$$

When the observation period t lengthens, θ_t will approach the true value θ.

The equations shown above are calculated under the following assumptions :

(1) the processing times of a job at different workstations are identically distributed with the same mean (workloads on workstations are assumed to be statistically balanced);

(2) failure do not occur at workstations;

(3) instantaneous job movement between workstations.

In order to compute production rates, the number of pieces and processing times for each job of each machine are then collected (as shown by Table 5.1). The Table also shows total production rate for each work center (i.e., the work center of shearing, punching, and bending). Notice that the production output from the work center of shearing is less than the production of the work center of punching and bending. There are two reasons why the quantities are not balanced, the first is because some components (such as wrapper, panel, base pan) which are sheared to size by sub-contractors need only the operations of punching and/or bending. The second is caused by the repetition of punching and/or bending operation, i.e., repeat operations by another machine at the same work center.

In Table 5.1, each value which is filled in column 2 from left is the summarization of total number of workpieces produced by each machine. The values in column 3 from left are the total processing times (including setup and run time) spent to manipulate the amount of workpieces shown in column 2. An average processing times (column 4 and 5 from left) are derived from the value in column 2 and 3.

Table 5.2 is the list of number of jobs completed at the observed time period t (for this study t = 170 hours).

The stacked-bar graph as displayed by Figure 5.8 shows an unequality of the rate of production for the three work centers. It can be seen that the production rate of shearing operation is less than the rate of punching operation ; the different is 1,510 pieces per day. The production rate of bending is less than punching and the different is 924 pieces per day. Due to the unbalanced rate between shearing and punching operations, downtime then appears at punch press machines. Unbalanced production rates between punching and bending operations

Table 5.1. Production rates.

Machine	Output (pieces)	Processing Time (hours)	Average		Percent
			Pieces/ hour	Pieces/ 8 hours	
S-1	14,532	123.0	118.2	709	34.59
S-2	25,530	114.3	223.5	1,341	65.41
Total	40,062	237.3		2,050	100.00
P-1	1,693	63.3	26.7	160	4.50
P-2	12,481	104.5	119.4	716	20.12
P-3	5,975	65.5	91.2	547	15.37
P-5	5,929	76.3	77.7	466	13.08
P-6	7,619	77.5	98.3	590	16.56
P-7	6,899	86.0	80.2	481	13.51
P-8	2,510	32.5	65.2	391	10.98
P-9	3,128	89.6	34.9	209	5.88
Total	46,234	595.2		3,560	100.00
B-1	18,115	136.9	132.3	794	30.11
B-2	9,024	113.5	79.5	477	18.09
B-3	17,256	128.2	134.6	807	30.64
B-4	12,860	138.2	93.0	558	21.17
Total	57,255	516.8		2,636	100.00

Table 5.2. Number of jobs departed from the shop.

	B-1	B-2	B-3	B-4	sum
Date					
1	10	11	8	6	35
2	15	9	9	14	47
3	14	10	14	9	47
4	9	6	5	2	22
5	11	0	6	3	20
6	4	0	4	0	8
7	22	21	9	8	60
8	9	10	6	8	33
9	11	11	10	6	38
10	17	3	11	5	36
11	17	13	7	15	52
12	10	12	5	9	36
				Total	434

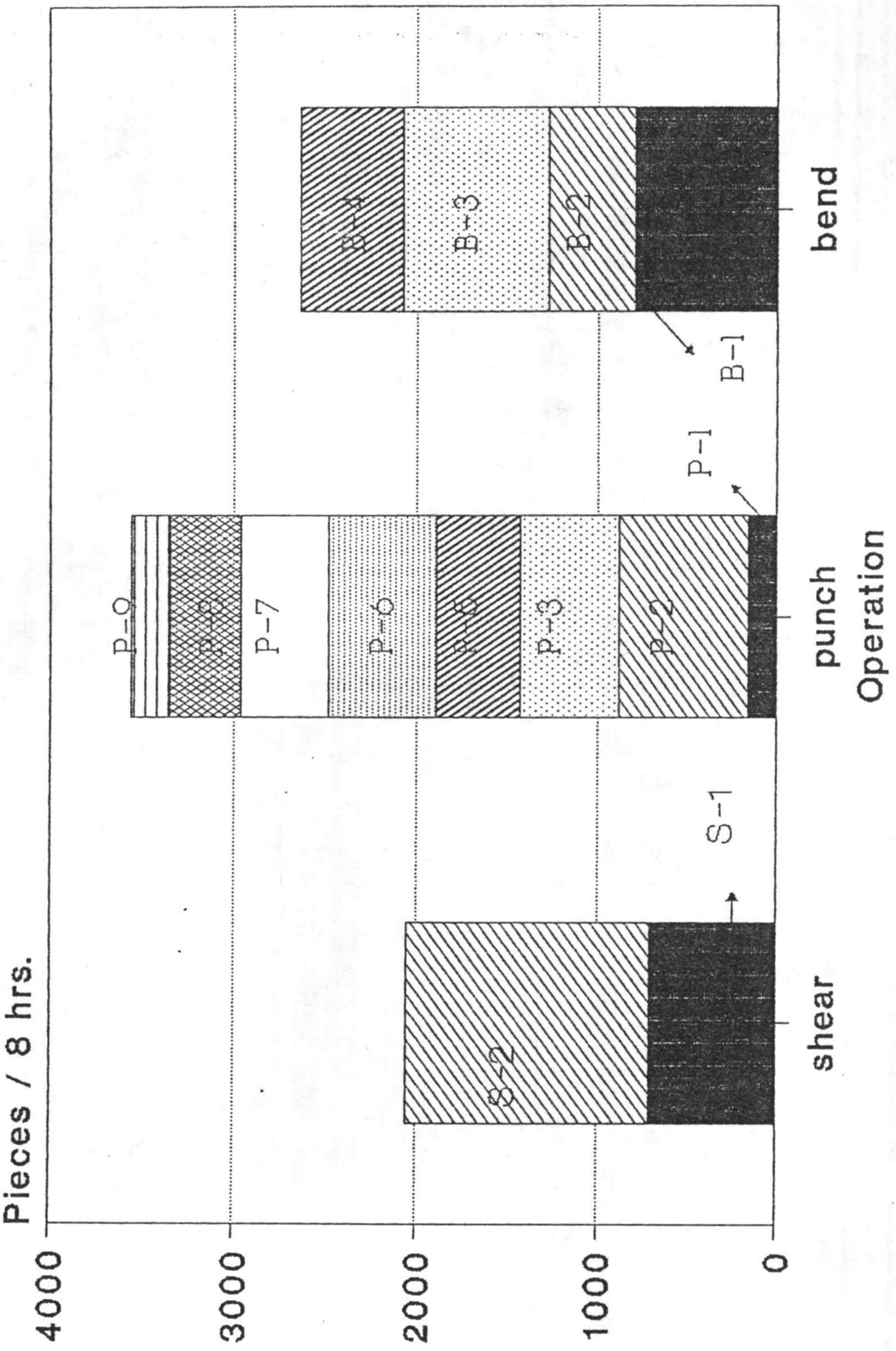


Figure 5.8. Graph shows work center production rates.

caused an accumulation of work-in-process at the shop. Additional shearing and bending machines are the a way to balance production rates.

We can compute the throughput index by using the formula as mentioned above.

The following are values of parameters :

t = 170 hours of observation period ;

n_t = 434 jobs departed from the shop;

m = 14 machines ;

$\sum_j \sum_i a_{ij}$ = 1349.3 hours.

Then

$$v_t = 170 \;/\; 434$$

$$= 0.392 \quad \text{hour / job}$$

$$\bar{a}_t = 1349.3 \;/\; (\; 434 \times 14 \;)$$

$$= 0.222 \quad \text{hour / job}$$

therefore, the throughput index value is

$$\theta_t = 0.392 \;/\; 0.222$$

$$= 1.77$$

If there is a shop with $\theta = 1.0$ it will be an ideal shop, operating without any idle time at any workstation. For this case, a shop operating with a throughput index $\theta_t = 1.77$ means that the time between departure will be 1.77 times greater than in an ideal shop with no machine idle time.

Since throughput index θ_t is the inverse of shop utilization, therefore shop utilization is 1/1.77 or 57 %. The utilization of this type of job shop should be improved to higher level than 57 %.

b) Productivity

Productivity is defined as the ratio of an input to an output.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

$$\text{Productivity} = \frac{\text{Output}}{\text{People + Material + Money + Energy}}$$

To best understanding productivity each of the areas in the denominator should be controlled by itself.

$$\text{People productivity} = \frac{\text{Units produced}}{\text{People in hours worked}}$$

Then answer is units produced per people hour.

$$\text{Material productivity} = \frac{\text{Units produced}}{\text{Material cost}}$$

$$\text{Money productivity} = \frac{\text{Units produced}}{\text{Money spent}}$$

Then answer is capital required per unit.

$$\text{Energy productivity} = \text{Units produced}$$

Then answer is energy cost per unit.

The productivity can be improved by making the best use of these four inputs. To eliminate the waste of these resources :

1. *People* : The most valuable asset that people have is time.

Time has a cost in business and lost time is a waste. The "blue collar" man loses his time when he is idle. This idleness is caused by delays due to setup, tooling, inspection, machine repair, instructions, material handling, and other. He also loses time if he must do rework, or if he must do special work when a previous operation has not been done correctly.

2. *Material* : Material waste consists of : planned waste (i.e., destructive testing, setup sample), scrap, rework, obsolence, theft, and shrinkage.

3. *Energy* : Unsuitable heating-temperature settings, unneeded lighting, and not using natural ventilation when outdoor conditions warrant are examples of lack of energy conservation practices.

4. *Money* : The wastes may be occurred in terms of material cost, labor cost, overhead cost, expense, etc.

Using the data from Table 5.1 and the productivity formula shown above, then the people productivity for each work center is

$$\text{People productivity for shearing work center} = \frac{\text{Units produced}}{\text{People in hours worked}}$$

$$= \frac{40{,}062 \text{ pieces}}{(237.3 \text{ hours})\times(7 \text{ workers})}$$

$$= 24.12 \quad \text{pieces/man-hour.}$$

$$\text{People productivity for punching work center} = \frac{46{,}234 \text{ pieces}}{(595.2 \text{ hours})\times(7 \text{ workers})}$$

$$= 11.10 \quad \text{pieces/man-hour.}$$

$$\text{People productivity for bending work center} = \frac{57,255}{(516.8 \text{ hours})\text{x}(12 \text{ workers})}$$

$$= 9.23 \text{ pieces/man-hour.}$$

Notice that production rate is the value of production output devides by processing time. But people productivity for each work center is an index value which is represented workers utilization. However, the utilization of worker is also depended on work complication.

Methods improvement for bending operation

The analysis of production rates from the previous section obviously indicated that sheet-metal components are blocked at the bending operation. Therefore, this work center should have its production rate increased either by adding a new press brake machine or by reducing waste time of operation for the current machines.

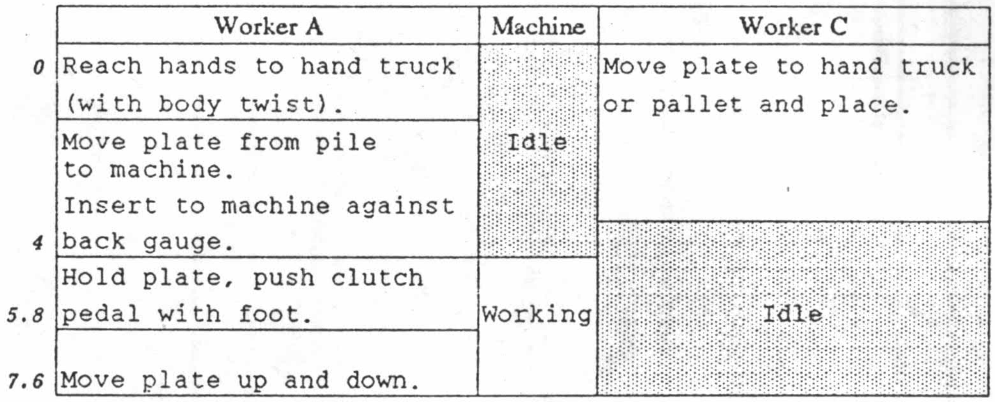
Normally, the stroke of a particular press brake machine is constant, but the work contents of loading and unloading a different size of workpiece is a main parameter that vary cycle times. The cycle times can be reduced by improving the method of operation.

Workpieces (referred to chapter 4) are classified as small, medium, and large size. A small plate can be operated by one worker and two or four workers are required when a medium or large plate is produced. Man-machine charts as displayed by Figure 5.9 represent the worker and machine when producing a small workpiece. If two workers do identical operations on one machine, production rate is probably increased two times. For a medium plate in the same manner, when using two workers (the chart is shown in Figure 5.10) the cycle time for one bend is 7.6 seconds and machine utilization equals 47.3 %. If three workers do the same job the cycle time is reduced to 5.4 seconds and machine utilization is then increased to 59.2 % as shown by figure 5.11. For the case of three workers, although the people productivity is slightly lower than the case of two workers but production rate is much higher. Backlogs in bending process are then reduced.

0	Worker A	Machine
1.5	Reach right (or left hand) to left (right) hand, grasp and move plate to machine against back gauge.	Idle
2.7	Hold plate, push clutch padal with foot.	Working
3.2	Lay aside plate on hand truck	Idle

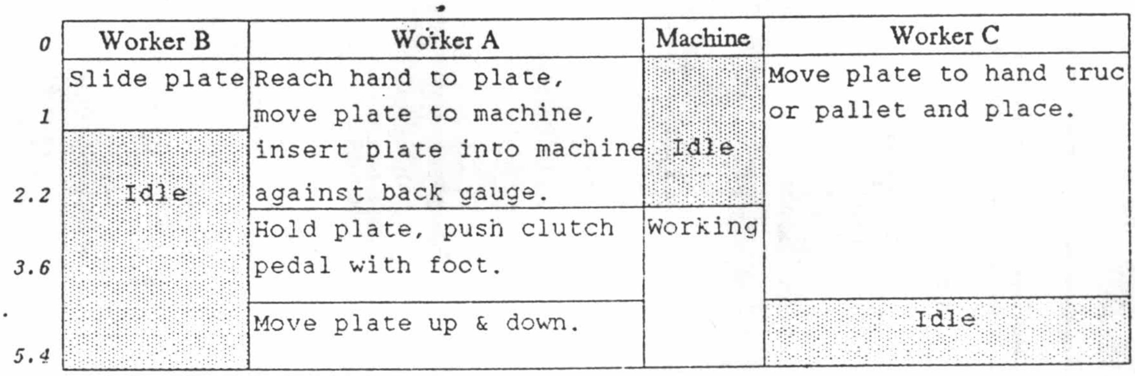
Cycle time = 3.2 seconds.
Machine utilization = 1.2/3.2 = 37.5 %

Figure 5.9. Man-machine chart in bending process (small workpiece).



Cycle time = 7.6 seconds.
Production rate = 355 pieces/hr.
Machine utilization = 3.6/7.6 = 47.3 %
Productivity = 177.5

Figure 5.10. Multiple-activity process chart for low machine utilization in bending operation (medium workpiece).



Cycle time = 5.4 seconds.
Production rate = 500 pieces/hr.
Machine utilization = 3.2/5.4 = 59.2 %
Productivity = 166.7

Figure 5.11. Multiple-activity process chart for high machine utilization in bending operation (medium workpiece).