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PRODUCTIVITY ANALYSIS AND IMPROVEMENT (STUDY CASE AT A COFFEE MANUFACTURER)

Debora Anne Yang Aysia[1], Kurniawati Setianingsih[2], Tommy Liman Sutanto[3]

[1]Faculty of Industrial Technology-Industrial Engineering Department
Petra Christian University, Surabaya 60236
Tel: (031) 2983433 Fax: (031) 8417658
debbie@peter.petra.ac.id

[2,3]Faculty of Industrial Technology-Industrial Engineering Department
Petra Christian University, Surabaya

A compatible operators' allocation is one way to improve the productivity of a manufacturing. With a good operators' allocation, the percentage of operators' idle time can be minimized. By the way, the production standard time is needed to determine the production capacity, in order to arrange a compatible operators allocation.The problem that occurred at PT X is the production capacity or target, which used as reference for scheduling the packing process, is determined based on company's experiences. So, the production standard time and capacity must be improved to be more valid and appropriate. Besides that, the compatible operators' allocation is needed. It is because most of the operators at these divisions were outsourcing. So it is important to know the suitable number of operators that must be recruited for a certain time. The same problem also occured at the supporting material warehouse. The objective of this research is to analyzes those problem and gives some improvement suggestions. The methods that are used to analyze are Stopwatch Time Study, Work Sampling, and Line Balancing.The results of this project are the company knows the standard time and capacity that can be used as a reference to set a daily production target, a better operators' allocation, and there are some suggestions that may improve their productivity.
Keywords: productivity, standard time, operators' allocation.

1. INTRODUCTION

Productivity improvement is very important in a manufacturing, because it can make the company increase their profitability. Productivity related to standard time. By knowing standard time to produce certain products, the production capacity can be calculated and it can be used to determine the daily production target. If the company does not know their production capacity, the operator could manipulate them, because they can work under their actual ability and then they have many idle times. It would inflict a financial cost for the company. Besides that, the compatible operators' allocation can influence the productivity of the operators. The allocation must be managed well so there are minimum idle times, but comfortable for the operators.

PT X is one of the biggest instant and roasted ground coffee manufacturers in South East Asia. It is a job order company which is the production depends on the customer's order. The productivity of packing process and warehousing process depends on the operator's performance, because almost all of the operations are done manually. So the operators play the most important role in these processes. But, the time to finish each product and the process' capacity are calculated, analyzed, and determined based on their experience. The company didn't know the exact level of their capability. Besides that, the compatible operators' allocation is needed. It is because most of the operators at these divisions were outsourcing. So it is important to know the suitable number of operators that must be recruited for a certain time.

2. THEORETICAL BACKGROUND

2.1. Productivity

Generally, productivity is the ratio of output per input (Barnes, 1980). Productivity will reach the maximum ratio if the output is increase and the other side the input is decrease. Here are some formulas that have been use in this paper:

$$\text{capacity/hour} = \frac{3600 \times \text{man power} \times \text{output in once operation}}{\text{the longest standard time} \times \text{capacity/box}} \quad (1)$$

$$\text{productive time} = \frac{(\text{capacity/hour(box)} \times \text{capacity/box} \times \text{std.time})}{(\text{man power} \times \text{output in once operation})} \quad (2)$$

$$\text{idle time} = 3600 - \text{productive time} \quad (3)$$

$$\%\,\text{idle} = \frac{\text{total idle time}}{\text{man power} \times 3600} \times 100\% \quad (4)$$

The productivity of man power is the ratio of output per man hour, which is the work hour that is needed to finish a job by a number of man powers. The formula is:

$$\text{productivity/man hour} = \frac{\text{total output}}{\text{the number of man power} \times \text{work hour}} \quad (5)$$

A man hour is the amount of work performed by an average worker in one hour. It is used in estimation of the total amount of uninterrupted labor required to perform a task.

2.2. Time Study

Time study may be used to determine the standard time that a qualified, properly trained, and experienced person should take to perform a specific task or operation when working at a normal pace. The result of time study is the time that a person suited to the job and fully trained in the specified method will need to perform the job if he or she works at a normal or standard tempo.

2.2.1. Stopwatch Time Study

Stopwatch time study is one of the direct measurements that suitable to measure the working time for repetitive job. There are three tests for the observation data, they are as follow:

a. Normality test.
b. Uniformity test.
   The Upper Control Limit (UCL) and Lower Control Limit (LCL) of the data can be calculated using these formulas:

$$UCL = \bar{x} + 3S \quad (6)$$

$$LCL = \bar{x} - 3S \quad (7)$$

Where:
$\bar{x}$ = average of data
S = standard deviation

c. Adequacy test.
   The formula if the amount of the data less than 30 can be seen at (8), otherwise can be seen at (9).

$$N' = \frac{(S \times t)^2}{(k \times \bar{x})^2} \quad (8)$$

$$N' = \left(\frac{\left(\frac{z_{\alpha/2}}{k}\right) \sqrt{\left(N \times \left(\sum x_i^{\,2}\right)\right) - \left(\sum x_i\right)^2}}{\sum x_i} \right)^2 \quad (9)$$

Where:
t = t-distribution at $\alpha/2$, with υ = n-1
k = degree of accuracy
$\bar{x}$ = average of data
S = standard deviation
x_i = i-th data
If N smaller than N', then the number of the data was insufficient.

Westinghouse rating system is the one of the rating system that usually used to determine rate of the operator's performance. There are four factors to be considered, they are skill, effort, conditions, and consistency. After determine the allowances, the standard time can be calculated using this formula:

$$\text{standard time} = \frac{\bar{x} \times \text{performance rating} \times 100\%}{100\% - \%\ \text{allowance}} \quad (10)$$

2.2.2. Work Sampling

Work sampling is a method of analyzing work by taking a large number of observations at random intervals, to establish standard and improve methods. The result of work sampling are effective for determining allowances applicable to the job, for determining machine and personnel utilization, and for establishing standards of production. The uniformity of the data can be tested by using these formulas:

$$UCL = p + 3\sqrt{\frac{p(1-p)}{N}} \quad (11)$$

$$LCL = p - 3\sqrt{\frac{p(1-p)}{N}} \quad (12)$$

Where:
p = percentage of events
N = number of observation
The adequacy of the data can be tested using this formula:

$$N' = \frac{k^2 \times p \times (1-p)}{s^2} \quad (13)$$

Where:
s = accuracy level
k = z value at $\alpha/2$

2.3. Line Balancing

The most elementary line balancing situation, yet on that is very often encountered, is a situation in which several operators, each performing consecutive operations, work as a unit. In such situation, the rate of production is dependent in the slowest operator. The efficiency of this line can be computed as follow:

$$Efficiency = \frac{\sum_{i=1}^{n} SM_i}{\sum_{i=1}^{n} AM_i} \quad (14)$$

Where:
SM = Standard minutes/operation
AM = Allowed standard minutes/operation
If there is an expected rate of efficiency (E) and certain rate of production (R), then the number of workers that needed is follow:

$$N = \frac{R \times \sum_{i=1}^{n} SM_i}{E} \quad (15)$$

2.4. Cause and Effect Diagram

The cause and effect diagram is used to explore all the potential causes that result in a single effect. Causes are arranged according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events. This can help to search for root causes, identify areas where there may be problems, and compare the relative importance of different causes. Causes are frequently arranged into several major categories, they are man, methods, materials, measurement, environment, and machinery.

3. RESEARCH METHOD

The steps to do this research are explained as follow:

a. Observing and surveying to know the production floor condition
b. Identifying and determining the problems that occurred in packing process and supporting material warehouse.
c. Observing and recording the time to finish each work element in packing and warehousing process.
d. Calculating and analyzing the data to get the standard time and capacity.
e. Analyzing the current condition of operator's allocation to get the best allocation during the process.
f. Analyzing the result of all observation and give the best suggestion to improve the packing process and warehousing process.
g. Validating and verifying the result and the suggestion.
h. Reanalyzing the suggestion and make the final conclusion.

4. RESULT AND DISCUSSION

4.1. Packing Division

The primary problem at packing division is there often produce under the target. The cause and effect diagram at Figure 1 shows the relation about that problem and its causes. There are four aspects that caused the problem. Those are the operators, measurement, material, and machine. The low productivity of operators that cause by the operators with low work effort makes them work not maximal and do not reach the target. The target is

defined based on experiences, so some of them were invalid. Sometimes they lack of materials because there is much defective product, which must be rejected. The troubled machine that must be repaired in certain time makes the production flow stopped for a while.

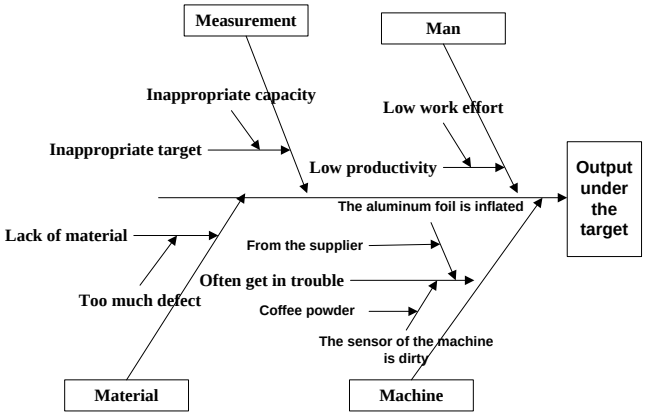

Figure 1. Cause and Effect Diagram

4.1.1. Standard Time and Standard Capacity

Knowing the standard time and the standard capacity for each product helps the company to determine their production target, make production schedule more productive, and allocate their operator effectively. As an example, here is the capacity calculation of packing process for product B. The longest standard time for this packing is filling pail activity, 44.22 second. By 5 work hours (18000 second), then the capacity is 18000 second/44.22 second = 407.03 pail/5 hours. The summary of the capacity calculation in the packing process can be seen at Table 1.

Table 1. Summary of the Packing Capacity

Product	Capacity/Hour	Product	Capacity/Hour
A	12.44	K – Second day	83.42
B	81.41	L – First day	362.76
C	13.16	L – Second day	158.28
D	15.15	M – First day	196.03
E	6.35	M – Second day	83.42
F	5.98	N – First day	68.45
G	15.05	N – Second day	41.71
H	61.26	O	40
I	48.52	P	13.02
J	70.21	Q	40
K – First day	181.38	R	61.44

4.1.2. Idle Time

Work sampling is used to know the rate of idle time, so it can be known the work affectivity of the operator. After the observations, it is known that the idle time of instant packing operator is 38.86%. It means that the production at instant packing division is less productive. There are many idle times that should not need to be happened. It also has been analyzed that the idle time was often caused by the machine that always get in trouble about 6.94% per day (7 work hours). The machine must be repaired in every certain time. This condition is caused by the aluminum foil that was not flat, so the sensor of the machine cannot read it. Besides that, sometime the sensor of the machine is dirty, so the operator must clean it first. It is surely affecting the packing process. The followed operation must be stopped for a moment and the operator was idle then. The output also decreases than it could reach and it caused more waste. Because of this condition, the machine must get more attention. The idle time also caused of unavoidable delay time from one operation that has longer time to another operation and another special caused, like the aluminum foil was defect or lack of supporting material (inner, oval sticker).

4.1.3. Operator's Allocation

Operator's allocation must appropriate with the work load and the time to finish a process that can increase their productivity. Most of the packing operators were outsourcing. Company recruit them depends on the customer's order and the production schedule. Company should know how many operators are needed at each of packing process, so company can recruit outsourcing operator at precise number. The number of operator must appropriate with the work load and the standard time of each process, so that the operator can work effectively and productively with minimum idle time.

The number of operators and its allocation are different for each packing process. There are some steps to adjust the allocation of the operators, those are:

a. Analyzing the current allocation of the operators, whether it can be improved.

b. Calculating and analyzing the number of operators that are needed by line balancing methods.
c. Calculating the productive time and idle time for the current allocation.
d. Trying to adjust and allocate the number of the operators from the calculation of the line balancing into each of the work element. Those numbers of operators may be not able to be applied because there are some constraint and condition that must be considered. If it cannot be applied, then trial and error method is used to find the best allocation of the operators.
e. Calculating the productive time and idle time for the proposed allocation.
f. Comparing the result of percentage idle of the current and proposed allocation.

Here is an example for product R. R packing process has 13 operators. Capacity = 368 box/shift (6 hours) and there are 8 work elements. Assumption: To compare the unit of output per work element, then it uses 1 Lot = 2 boxes, then capacity = 184 lot/shift (6hours). The initial Efficiency is follow:

$$Efficiency = \frac{423.18}{8 \times 117.19} = 45.13\%$$

To improve the efficiency until 85% (based on the company's expectation), then the number of operators that are needed is:

$$N = \frac{184 \times 423.18}{21600 \times 0.85} = 4.24 \approx 5 \; operators$$

The calculation shows that it needs 5 operators. This result is very different with the current number of operators. It is impossible to use only 5 operators because there are 8 work elements. We can see that the formula only consider about production target and the sum of standard or allowed production time, but never consider about the work elements. Because we cannot apply the formula, then we use trial and error method to find the best allocation of the operators. As a result, the number of the operator can be reduced by 2 operators, so there are only 11 operators in this process. It needs to be further analyzed by comparing the idle time and productive time, which can be seen at Table 2 and Table 3. The percentage of idle time decrease until 6% and it means the productivity of operators is increase.

Table 2. Current Condition for Product V

Work Elements	Man Power	Std. Time (s)	Capacity/ hour (box)	Productive (s)	Idle (s)	Total Idle (s)	% Idle
Filling Sachet	1	1.2	61.44	-	-	7950	16.99
Filling Inner	4	10.77		2646.15	954		
Checking Inner	2	5.43		2669.61	930		
Gluing	2	7.32		3600	0		
Filling Box	2	3.99		490.41	3110		
Checking Box	2	5.47		644.26	2956		
Packing		8.99					
Coding		6.51					

Table 3. Proposed Condition for Product V

Work Elements	Man Power	Std. Time (s)	Capacity/ hour (box)	Productive (s)	Idle (s)	Total Idle (s)	% Idle
Filling Sachet	1	1.2	61.44	-	-	4349.57	10.98
Filling Inner	4	10.77		2646.15	953.85		
Checking Inner	2	5.43		2669.61	930.39		
Gluing	2	7.32		3600	0		
Filling Box	2	3.99		1134.67	2465.33		
Checking Box		5.47					
Packing		8.99					
Coding		6.51					

The comparison summary for current and proposed condition of operator's allocation in the packing process can be seen at Table 4. There are some processes which already have a precise condition, so there is no proposed condition. There is also a process with has no reduction for the number of operators, but the idle time can be reduced by rearranging the operator's job.

Table 4. Comparison Condition of Packing Process

Product	Number of Operator		% Idle	
	Current	Proposed	Current	Proposed
A	6	5	28.96	14.75
B	5	4	39.78	24.72
C	4	-	26.39	-
D	4	-	24.06	-
E	4	-	3.24	-
F	4	-	4.36	-
G	3	3	58.89	25.55
H	6	5	40.02	28.02
I	6	5	45.56	34.67
J	14	10	24.4	8.78
K – First day	18	15	21.84	14.23
K – Second day	16	15	6.2	5.7
L – First day	18	15	21.84	14.23
L – Second day	16	15	4.56	4
M – First day	18	15	20.92	12.69
M – Second day	16	15	6.2	5.7
N – First day	18	15	24.66	18.92
N – Second day	16	15	7.57	7.17
O	13	-	16.27	-
P	18	10	25.22	23.17
Q	16	14	22.59	18.27
R	13	11	16.99	10.98

4.1.4. Man Hour Analysis

Productivity per man hour under different conditions are compared each other. Table 5 shows the example of the comparison.

The capability of realization data was taken from the company's packing report. The capability of record data was taken from the company's packing record that has been determined base on company's experiences. The capability of standard data was taken from the calculation of the standard packing time. The capability of proposed data was taken from the proposed operator's allocation.

Table 5. Productivity/Man Hour Comparison

Product	Realization	Record	Standard	Proposed
A	0.83	1.33	2.07	2.48
B	8.28	12	16.28	20.35
G	2.76	5	5	5
H	3.91	3.33	10.19	12.23
I	3.4	3.06	8.08	9.7
J	4.56	3.57	4.68	7.01
O	2.07	4.17	3.08	3.08
P	0.47	6.25	0.87	1.3
Q	3.37	2.5	2.35	2.85

The comparisons of man hour above show that almost all of the productivity/man hour of standard data is higher than either record data or realization data. It can be analyzed that up till now the packing process is not effective enough. The operators are still working under their actual ability. They should be able to reach the target more than they have already reached. Company should use the man power maximally, if they want to increase their output and productivity.

4.1.5. Improvement

After analyzing the situations and conditions of packing division, there are some suggestions for company to increase their productivity:

a. Set the target

Actually, company already has the target based on experiences, but not all of these targets can represent the actual condition. So, a new target based on the standard capacity is needed.

b. Have a decisive attitude to the operators

The condition of the operators at packing process is often not in orderly. The supervisor of packing process must pay more attention, so there are not activities that disturbing the production. They must organize the packing process floor so the operators can work comfort and productively.

c. Incentive Plan

Incentive plan is one of the methods to increasing the productivity of the operators. Incentive can motivate the operators to work more seriously. The incentive plan that is suggested is Piecework Rate, because it is the simple and suitable with the condition of the packing process.

d. Hire the outsourcing as much as needed

The analysis of operator's allocation helps the company to determine how many outsourcing that must be hired in a certain time, so that they can work productively and effectively. It is tried so that the idle time can be minimized and the operators work productively.

e. Reallocate the idle operators

The packing process has many idle times, because of the uncertainty order, while there are some outsourcing operators that still contracted. Supervisor and foreman must reallocate those operators to do the other activities, like cleaning, preparing the next packing process, or send them to other sections that need to be helped.

f. Packing Record and Daily Report

Packing record is very important to supervisor or manager to know the condition and realization of packing process each day. Those packing record can be different depends on the type of packing process.

g. Daily machine report

The machines always get in trouble every certain time and for a day the machine get idle about 7%. There must be a daily machine report that is posted to technician manager, so if there are some problems, the technician division can handle it directly.

h. Increase the marketing and selling rate

The standard capacity shows the ability of the operators to produce. But the real condition shows that the orders were too less. Actually, the company can produce more than the order from customers that have already accepted up till now. The marketing division must work more persistent to get more customers and increase the orders, so company can

maximize their profit.

4.2. Supporting Material Warehouse

The problem at supporting material warehouse is at bottles preparation activity. Company wants to know the capacity for spraying and washing bottles per day, because the instant packing process for bottling depends on the availability of those bottles, so that the PPIC staffs can make packing process schedule better. When the packing process needs those bottles, it has been available.

All of the operators at this section are outsourcing. It is important for the company to know how many operators should be hired for a certain period to clean the bottles. The number of operators is tried not too much but they can work productively.

4.2.1. Standard Time and Standard Capacity

The summary of the capacity calculation in the supporting material warehouse can be seen at Table 6.

Table 6. Warehouse Capacity

Bottle	Capacity
A	4275.5 bottles/8 hours
B	2366.65 bottles/7 hours
C	2250.4 bottles/ 7 hours

4.2.2. Operator's Allocation

The activity of washing bottles is occasionally depends on the order of products with bottle packaging. Because of this condition, all of the operators are outsourcing that are recruited for certain period. The number and allocation of the operators will influence the process and the output. The comparison summary for current and proposed condition of operator's allocation in the supporting material warehouse can be seen at Table 7.

Table 7. Comparison Condition of Supporting Material Warehouse

Bottle	Number of Operator		% Idle	
	Current	Proposed	Current	Proposed
A	10	6	33.82	18.34
B	12	10	34.98	21.97
C	11	10	32.1	25.31

4.2.3. Improvement

After analyzing the situations and conditions of supporting material warehouse, there are some suggestions for company to increase their productivity:

a. Set the target

The standard capacity can be set as the target for the operator to clean the bottles in a day. This target can be reference to determine how long the company must contract the outsourcing to clean the bottles and for PPIC to schedule the packing process.

b. Hire the outsourcing as much as needed

The outsourcings that are contracted for a certain time must be appropriated with the necessity. The analysis of operator's allocation may be a reference for the company to determine the number of the outsourcing that must be hired.

c. Cleaning Bottles Report

There is no cleaning bottles report which is given from the foreman to the supervisor up till now. The purpose of that formal form is the company can know how many bottles that have been cleaned or washed daily. Besides that, the company does not need to be afraid of missing data. And the administration in this section can work in orderly.

5. CONCLUSION

The standard time and capacity for each packing process, as a target to be fulfilled by the operators, must define first in order to increase the productivity. Then, the operator must be well allocated, so the idle time can be minimized. There is proposed allocation that can decrease the idle time. Those allocations can be reference for company to hire the outsourcing as much as they need. One of the obstacles to maximize the productivity is that the

operators only can work depend on the order, whereas the orders are uncertain and sometimes not too much. This condition makes the operators sometimes have not any works. If there are some operators that get idle, the foreman or supervisor must reallocate them, tried so that they are not in idle. The foreman and supervisor also must have a decisive attitude to the operators. They must warn the operators that are not discipline and motivate them to do their work seriously. To simplify controlling the activities of the operators, there should be a daily report, besides the packing record. This report such as a responsibility report for what they have done in a day. On the other hands, to increase the productivity, the marketing division must work more persistent to get more orders, so the company shall not loss to hire the outsourcing because they can empower the operators maximally.

Knowing the standard capacity of cleaning bottle process is very important, because this activity has an impact to the scheduling of bottle packing process. Standard capacity can be set as daily target for the operator, so it can be known how much time is needed to prepare the bottles. PPIC can also schedule the bottle packing process better.

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