Implementation Learning and Forgetting Curve to Scheduling in Garment Industry

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Abstract. The learning curve shows the relationship between time and the cumulative number of units produced which using the mathematical description on the performance of workers in performing repetitive works. The problems of this study is level differences in the labors performance before and after the break which affects the company's production scheduling. The study was conducted in the garment industry, which the aims is to predict the company production scheduling using the learning curve and forgetting curve. By implementing the learning curve and forgetting curve, this paper contributes in improving the labors performance that is in line with the increase in maximum output 3 hours productive before the break are 15 unit product with learning curve percentage in the company is 93.24%. Meanwhile, the forgetting curve improving maximum output 3 hours productive after the break are 11 unit product with the percentage of forgetting curve in the company is 92.96%. Then, the obtained 26 units product on the productive hours one working day is used as the basic for production scheduling.

1. Introduction:
The company productivity will have a very close relationship with the effectivity which towards to target achievement including quality, quantity and time. According to [1], productivity is a measurement in deciding how good is the natural resources that have been applied together in order to achieve some results.

Factor that affected productivity level can be used as a measuring rod in work performed measurement. Factor that affected work performed was an individual factor, including work experience, education

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level, individual motivation in developing themselves and occasional factor. Some repetitive works will increase work experience so that the workers will remember all the process spontaneously or unexpectedly. The effect of it, workers will find fast and suitable problem solving through economic strategies or movements that shortening the working time. This condition showed that the workers have been through the learning process or called as learning by doing. This phenomenon or symptom can be explained through or by learning curve.

Wahab and Jaber [2] reported that the benefit of log-linear learning curve can be applied in production planning activity. According to [3] in his research about schedule arrangement based on the learning curve, schedule arrangement based on education level can be accepted since Biskup [4] stated that the learning curve as a strengthening function in some works. Hurley [5] showed that based on the actual time given, working time is decreasing because of increasing in working quantity. [6] Stated the importance of using the learning curve for problem solving in industries.

The issues in garment industries are about the difference in performance level. It will give impact to the arrangement or scheduling of company production. There are some differences of performance level before and after break time. It happens due to the absence of advanced learning process. Therefore, learning curve application is needed as a reference base for measuring the learning level of a company. So in the future evaluation, it can be used as an improvement process for company management, especially in company production scheduling or arrangement.

2. Literature Review
Previous research proved that the learning curve can be implemented in company for measuring the productivity. According to Blancett [7], Globerson and Gold [8], log linear learning curve is the most common learning curve that have been used to predict the production level in repetitive operation. This model described the mostly manual-based operations with acceptable precision [9]. Then Wahab and Jaber [2] reported that the benefits of log linear learning curve can be applied to production planning activities. Terwiesch and Bohn [10] suggested this model are useful in assessing the learning effected of the whole process from new model as well. Malyusz [11] also predicted the upcoming performance by using the learning curve, stated that math’s learning curve can be used in construction to predict the time and cost needed in creating repetitive operation.

According to Lee [3] examined the learning curve based scheduling, scheduling with due regard to an acceptable level of learning since Biskup [4] suggested a learning curve as a function of the strength of a job. Hurley [5] showed that by the time the actual process was given, the processing time will go down because of the increased amount of work. Badiru [12] implemented lean manufacture through learning curve model to predict the amount of the workers. The approached of scheduling problems also stated by Anzanello and Fogliatto [13], with the completed work based on workers learning process and earliness weighting total and tardiness that need to be optimized.

From the literature review, we can conclude that there is no research that have been done in garment industries to be precise in Lullabic Convection. This study will review the scheduling with learning and forgetting curve model to detect the company learning level and the maximum output that can be produced during the company effective hour.

The learning curve shows the relationship curve between time and cumulative quantity of units produced which is a mathematical description of the performance of employees in performing repetitive work.

3. Learning Curve
Learning curve in the production system is a curve line showing the relationship between the time required for the production and the cumulative number of units produced which is a mathematical description of the performance of workers doing repetitive work.
3.1 Learning Curve Model

According to Wright [14] looking at how aircraft assembly costs decreased due to the repetition of the work performed. There are five models is the Learning Curve

![Learning Curve Model]

3.1.1 Log Linear Linear

\[ T_N = KN^s \]  

Specification:
- \( T \) = time to produce a unit to \( N \) (second)
- \( K \) = time to produce the first unit (second)
- \( N \) = unit to \( N \)
- \( s \) = slope

While to find the magnitude on the slope of the learning curve can be used equation below:

\[ T_1 = \frac{\sum T_i}{N} \]  
\[ T_N = \frac{\sum T_N}{N} \]  
\[ T_{2N} = \frac{\sum 2N}{N} \]  
\[ S = \frac{\log(T_{2N})}{\log 2} \]  
\[ \theta = 2^s \]

Parameter \( s \) (slope) are between \(-1 < s < 0\) is the slope of the learning curve line that describes the level of learning workers. \( S \) value near to \(-1\) indicates a high level of learning and adaptation speed to carry out the job [12,15–17]. Negative slope because the effort (time) decreased with an increase in production.

3.1.2 Plateau Model

\[ T_N = K + KN^s \]  

In this model \( K \) is added to the model of Log – Linear while \( K \) is a constant steady state performance of workers. Referring to the equation:

\[ \log T_i = \log K + s \log N_i \]
On the Plateau model, the condition steady state concluded after learning was completed or when the limitations of the machine development or learning on workers[1,17,18].

3.1.3 B Stanford Model

\[ T_N = K(N + B)^5 \]  

(9)

The constant B, presented the availability of an equivalent unit at the commencement of the experiment. Generally, B has a value of 1-10, in the general case the value 4 [19].

3.1.4 De Jong Model

In the generally De Jong model, the learning curve was calculated by combining the effect of machine/tool on a learning curve. By the following equation:

\[ T_N = K[M + (1 - M)N^5] \]  

(10)

M is the ratio between cycle time after an unlimited quantity of repetitions and cycle first time. When the value of M (0 ≤ M ≤ 1) is the incompressibility factor explaining that a small portion of work were carried out using tools [5,18]. When the value of M = 0 means no assistance tool in carrying out tasks or jobs done manually. When M = 1 explains that the job entirely completed by machine or no learning at all [5].

3.1.5 S Model

The model S curve is purpose to describe learning occurs when the intervention with the machine, and the first cycle of operation request. Model S is the result of an integration of the model De Jong and Stanford-B, as in the following equation:

\[ T_N = K[M + (1 - M)(N + B)^5] \]  

(11)

3.2 Forgetting Curve (FC)

Forgetting curve describes memory decline in unit time. Related concept is the power of memory which refers to the durability of memory in the brain. The strongest memory in a long period of time, then that person will be able to remember it. According to Jaber and Bonney [20], the time to produce the first unit in the cycle \( i \) predicted from Wright learning curve so that the intercept forgetting curve. To calculate the forgetting curve with LFCM models, the equation below can be used:

\[ T_N^{LFCM} = K(\theta + N)^e \]  

(12)

3.3 Scheduling

Scheduling is the process of allocating resources to select a set of work tasks in a certain period. Jobs Scheduling in manufacturing and service industries become an important research topic in the literature [21]. Anzanello and Fogliatto [13] proposes an approach to scheduling problems in which the work is completed depends on learning the process of worker. The learning curve can be used to measure the performance of worker on assignment of new models in a given assembly line today, and the previous models that have been produced. Job scheduling more realistic should arise by considering such information. Examples scheduling based on the learning curve is to determine the maximum output at the company productive hours can be scheduled based on these data.

3.4 Allowance

Allowance is given for three things, that is for personal needs, relieve fatigue, and barriers that cannot be avoided. All three constitute the real thing needed by workers and not observed, measured, recorded, or calculated during the measurements.
4.0 Result and Discussion
Data processing has shown the calculation and results obtained for each dimension. It is then elaborated in chapter below.

4.1 Allowance
The owned time of a worker from start the job until the break is 4 hours. With allowance is 27.5%, which can be seen in Table 1. It is known that the productive hours at a time before the break is during the 3 hours (10800 seconds) productive.

| No  | Factor              | Description                     | Allowance (%) |
|-----|---------------------|---------------------------------|---------------|
| 1   | Personal needs      | Man                             | 2.5           |
| 2   | Eliminating fatigue |                                 |               |
| a.  | Power was issued    | Can be ignored (working at the table, sitting) | 5             |
| b.  | Working attitude    | Sitting                         | 1             |
| c.  | Working movement    | Normal                          | 0             |
| d.  | Eye fatigue         | Nearly continuously view        | 5             |
| e.  | Temperature condition | Normal                       | 3             |
| f.  | Atmosphere condition | Enough                       | 3             |
| g.  | Environment condition | Repetitive working cycle 0-5 second | 3             |
| 3   | Barriers are not inevitable |                                | 2.5           |
|     | Total               |                                 | 25%           |

4.2 Learning Curve Each Station
Each station was calculated from five models of learning curve existing. Then the model was selected with the smallest error values. Based on the data pattern, model B-Stanford was selected after observing the behavior of workers during the current observation. Here is a recapitulation of the learning curve of each workstation in the sewing section.

![Figure 2. Recapitulation of the learning curve of each workstation](image.png)
Based on Figure 2, level of learning curve at each work station can be seen. The result of percentage achieved at station 1 or in the process of making the lid pocket product by using learning curve is 76.05%. While, the result of percentage achieved in the process of making the main pocket product is 89.06%, outside blekser 98.46%, rear body 59.32%, blekser in 87.29%, sleeve 72.02%, collar 94.5%, obras 87.53%, labelling 92.49%, fixing sleeve 94.09% and bottom kelim 94.49% respectively.

The highest percentage of learning at the third station with a percentage of 98.46% and the lowest is 4 stations with percentage 59.32%. At the station 3 and 4, there is a difference in percentage of learning as much as 39.14%. This difference of percentage can be influences by many factors, such as differences in adaptation operator level, operator experience level, the difficulty level in working on each task and also includes fatigue factors that occur in operator.

4.3 Learning Curve in the Company
This sections explained on a measure the level of learning for the company by the results of sum of the learning curve from each station on the sewing.

![Learning Curve in the Company](image)

**Figure 3. Learning Curve in the Company**

Based on Figure 3, it shows that the learning curve percentage of the company is 93.24% with a slope of -0.10098 which showed that the level of learning and adaptation speed in carrying out the task in this company is not so high. The percentage of the learning curve showed a maximum of 3 hours of productive output before the break for 15 units with a cumulative time of 10558.65 seconds can be seen in the table 2.

| No | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| LC | 846| 789| 757| 736| 719| 706| 695| 686| 678| 671| 664| 658| 653| 648| 644|
|    | 814| 569| 894| 194| 791| 660| 745| 427| 311| 133| 704| 890| .58 | 713 | 209|

4.4 Forgetting Curve (FC) in the Company
The forgetting curve of the company was calculated by using the process time of workers taken after the break and the sum of the forgetting curve of each station. Based on the figure 4, the obtained percentage forgetting curve of the company is 92.96%.
Figure 4. Forgetting Curve in the Company.

Table 3. Output 3 hours productive after the break

| No | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| LC | 1022.7 | 980.6 | 951.9 | 930.4 | 913.2 | 899.0 | 886.8 | 876.2 | 866.9 | 858.5 | 851.0 |

Based on Table 3, the results obtained from output 3 hours productive after the break on $T_3$ is 1093.14 seconds by using the average time. The percentage of the company’s learning curve is 93.24%. The N maximum obtained is 11 units with estimated time 10037.77 seconds. To determine the maximum output difference before and after the break used the learning curve percentage a company amounted to 93.24%.

4.5 Scheduling
In early observations, the average of shirt product produced in a single day as much as 22 products with the 8 work hours a day (there is no productive work time calculation). For production scheduling

Figure 5. The combination of Learning and Forgetting Curve
at the company has not been done reliable. Based on Figure 5, the number of maximum output at the company productive hours can be calculated after the implementation of learning and forgetting curve.

The company can produce 26 units product in one day by a margin before and after the break is 4 units. By using the maximum output, the production schedule for the company can be done. So if labor has done the work for 8 hours per day, the productive time which was taken is 6 hours (3 hours before and after the break then within one working day can be produced 26 products). Because the system in this company is the Make To Order (MTO) so the number of units that will be produced and production scheduling will be adjusted by a number of customer orders at the time. For example, if the company received orders for 1000 products, then in accordance with the maximum output that the company produced as many as 26 units so that production can be scheduled more or less completed within 39 working days. By this data the company can use it as a reference in production scheduling, scheduling of raw materials or scheduling of engine maintenance if necessary.

5.0 Conclusion
The findings of this study suggest that the learning curve and forgetting curve percentage of the company as 93.24% and 92.96%, respectively. The output that can be generated during 6 productive hours is as much as 26 products which are used as the basis for production schedule. From this result of the study recommended to do the continued study by calculating the fatigue factor to change the length of time workers or workers break.

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