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IMPLEMENTATION LEARNING AND FORGETTING CURVE TO PREDICT NEEDS AND DECREASE OF LABORS PERFORMANCE AFTER BREAK

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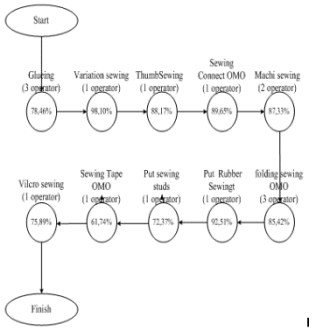
Graphical abstract



Abstract

A company needs to implement production planning to minimize time and cost. Forecasting and scheduling are two methods which should be conducted in production planning. By implementing the learning and forgetting curve methods, the labor needs as well as the decrease of labors performance after break can be predicted. Firstly, various learning curve models are presented, then each model was analyzed one by one so that the model with the smallest error rate could be determined. A case study conducted in the learning curve model is presented with data derived from the production floor. The four main purposes of this study were to calculate the percentage of each station learning curve, learning and forgetting curves in the company, minimum initial cost, and predict the number of employees needed for the lowest in the number of the work station company. The results in the percentage achieved for the learning curve is 91.47%, the gluing station 78.46%, variation sewing station 98.10%, thumb sewing station 88.17%, omo connect sewing station 89.65%, machine sewing station 87.33%, omo folding sewing station 85.42, rubber tide sewing station 92.51%, sewing station tide studs 72.37%, omo tape sewing station 61.74%, and vilcro sewing station 75.89%, respectively. By analyzing the percentage of each station learning curve, a comparison between the highest and lowest percentage learning curve on the company was made. Thus, it is known that omo tape sewing station needs another operator as the additional labor. The percentage of the forgetting curve is 91.59%. Through a search conducted on the cumulative hours of the productive company, the initial cost of production can be minimized to 15.600 Indonesian rupiah.

Keywords: Learning Curve (LC), Forgetting Curve(FC), Predicting, Scheduling

Abstrak

Sebuah syarikat perlu melaksanakan perancangan pengeluaran untuk mengurangkan masa dan kos. Ramalan dan penjadualan merupakan dua kaedah yang perlu dijalankan dalam perancangan pengeluaran. Melalui kaedah lengkung pembelajaran dan lengkung kelupaan yang dibuat keperluan tenaga kerja serta penurunan prestasi buruh selepas rehat dapat diramalkan. Pada awalnya, pelbagai model lengkung pembelajaran dibentangkan, kemudian setiap model dianalisa satu-persatu bagi menemukan model yang mempunyai kadar ralat terkecil. Sebuah kajian kes yang dijalankan dalam model lengkung pembelajaran dibentangkan dengan data yang diperolehi daripada kawasan pengeluaran. Empat tujuan utama kajian ini dijalankan adalah untuk menghitung peratusan bagi setiap lengkung stesen pembelajaran, lengkung pembelajaran dan lengkung kelupaan dalam syarikat bagi meminimakan kos permulaan dan meramalkan jumlah bilangan pekerja paling rendah yang diperlukan di stesen kerja syarikat. Keputusan yang diperolehi dalam bentuk peratusan bagi lengkung pembelajaran adalah 91.47%, 78.46% bagi stesen pelekatan, 98.10% bagi stesen jahit variasi, 88.17% bagi stesen jahit ibu jari, 89.65% bagi

stesen jahit sambungan omo, 87.33% bagi stesen mesin jahit, 85.42% stesen jahit melipat omo, 92.51% stesen jahit getah menaik, 72.37% stesen jahit stud menaik, 61.74% stesen jahit pita omo, serta 75.89% stesen jahit vilcro. Selepas mengkaji peratusan pada setiap stesen lengkung pembelajaran, perbandingan dibuat diantara peratusan lengkung pembelajaran yang tertinggi dan terendah di syarikat tersebut. Jadi, dapat diketahui bahwa stesen jahit pita omo memerlukan seorang lagi pekerja tambahan. Peratusan bagi lengkung kelupaan adalah 91.59%. Melalui satu kajian yang dijalankan terhadap jam kumulatif di syarikat yang produktif, kos permulaan bagi pengeluaran boleh diminimakan kepada 15.600 Rupiah Indonesia.

Kata kunci: Lengkung Pembelajaran (LC), Lengkung Kelupaan(FC), Meramal, Penjadualan

1.0 INTRODUCTION

Time and cost reduction program on the production floor planning is an important activity in the company. Bump [1] suggest that to incorporate the learning phenomena in costings, standard report will have to exert more meaning to management control. Many researchers argued that the learning curve is suitable to predict something on the production floor. The learning curve is a mathematical description of an employee performance when doing repetitive tasks [2,3,4]. The term learning curve was first introduced by Wright [4] to mark a phenomenon that occurs when a person is doing the same job repeatedly. As the working unit increases, the average time per unit to do the job is faster. For example, Biskup [5] showed that the iterative process of similar tasks improve the labor skills so that they are able to do set-up, to handle operations and machine software, or to handle raw materials and components with greater velocity.

The learning effect models on *job-position-based* on the actual job processing time is a function of the scheduler position and skill [5]. It showed that the scheduling problem of *two-single-machines* can be solved *polynomially*. Li and Rajagopalan [6] discussed the effects of the learning model that have not been realistic and simple which have the flexibility to easily describe different learning curves and able to generate the optimal solution to some scheduling problems. Jaber and Glove [7] developed new learning curve models which have cognitive and motor components. Assumptions that do not match the learning curve can generate excessive inventory policies, production levels and inventory levels. Furthermore, Malyusz and Pem [8] described the results of an exploratory study to evaluate the predictive ability of various learning curves and methods of presenting data for the labor-intensive construction operations.

Chairul Saleh [5] had performed a study showing that the Stanford B model and the average cumulative and average exponential provide the best prediction of the future.There are several factors that can affect the learning curve, such as changes in staff, design and company procedures. Indra Gunawan [8] applied the learning curve to manage employees' working time so that one can predict an employee hours needed and make timely production scheduling. The problem that appears is the suitability of the data obtained from the company with an existing learning curve model. Therefore, the required research or verification of the learning curve model can be obtained by comparing them. Based on the research results there is evidence which shows changes in the employee's performance after taking a break.There are work attitudes that are often forgotten after the break. Basically the curve shows the same tendency after the break but there is a decrease in performance, and this is called the forgetting curve.The issue that arises is the extent of the decrease in labor performance after taking the break.

2.0 RESEARCH METHODOLOGY

The study was conducted in a company that manufactures gloves, by observing the labor performance with respect to the number of product produced per unit time. These measurements were performed using a stopwatch. Data processing was conducted using *Microsoft Excel* 2007. The collected data were then tested for adequacy. Later, the learning curve calculation at each station by using the five models was performed. One of the models will be selected through the calculation of the smallest error rate. The determination for the minimum initial costs and predictions of the labor requirements was done by calculating the learning and forgetting curves of the company, as well as calculating the maximum output on productive hours.

2.1 Data Adequacy Test

To determine the adequacy of the data obtained in the study we can refer to Equation 1.

$$N' = \left(\frac{k/s \sqrt{N \sum X^2 - (\sum X^2)}}{\sum X} \right)^2 \quad (1)$$

Explanation:
K = the level of trust

S = degrees of accuracy
N = the number of data
Data can be assumed as sufficient if N' ≤ N.

2.2 Learning Curve

The learning curve is a mathematical description of the performance of labor in performing repetitive work [2,3,4]. The overall learning curve model is shown in Figure 1:

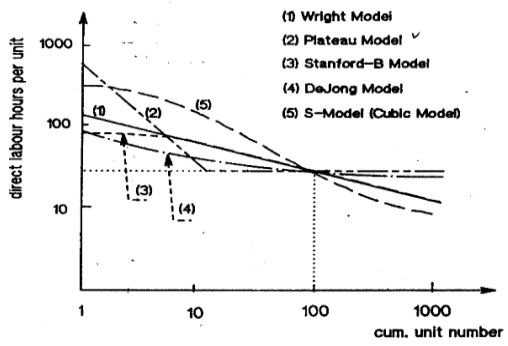


Figure 1 Learning curve models

2.3 Learning Curve Model

There are five learning curve models:

2.3.1 Model Log – Linear

Equation 2

$$T_N = KN^S \quad (2)$$

Explanation:
T = time to produce N[th] unit (second)
K = time to produce the first unit (second)
N = N[th] unit
S = slope
To determine the slope magnitude of the learning curve:
Equation 3

$$\bar{T}_1 = \frac{\sum T_1}{N} \quad (3)$$

Equation 4

$$\bar{T}_N = \frac{\sum T_N}{N} \quad (4)$$

Equation 5

$$\bar{T}_{2N} = \frac{\sum 2N}{N} \quad (5)$$

Equation 6

$$s = \frac{\log\left(\frac{\bar{T}_{2N}}{\bar{T}_N}\right)}{\log 2} \quad (6)$$

Equation 7

$$\theta = 2^s \quad (7)$$

Parameter s is the slope of the learning curve line that describes the learning level of workers, which ranges between -1 < s < 0, s value approaching -1 shows high levels of learning and adaptation speed to carry out the task [11,2,12,13]. According to Chairul Saleh [8] negative slope occurs when the effort is decreased with an increase in the production rate.

2.3.2 Plateau Model

Equation 8

$$T_N = K + KN^S \quad (8)$$

In the Plateau model, the constant K describes the performance of the Steady state workers. K is added to the log-linear models such as

Equation 9 $\log T_i = \log K + s \log N_i$ (9)

2.3.3 Model B Stanford

Equation 10

$$T_N = K(N + B)^S \quad (10)$$

K, B, s= constant parameters, always estimated through experiments and considerations, parameter B presenting equivalent units availability of experiments at the commencement of the experiment. Generally, B has a value 1 – 10, whereas value 4 is often used in the general case.

2.3.4 Model De Jong

Equation11

$$T_N = K\,[M + (1 - M)N^S \quad (11)$$

M is the ratio between the cycle time after an unlimited quantity of repetitions and the first cycle time. When the value of incompressibility factor, M (0 ≤ M ≤ 1) it explains that a small portion of work is carried out by using tools [13, 2]. When the value of M = 0, it means that no tool assists in carrying out the tasks or jobs done manually. The value of M = 1, explains that the job is entirely done by the machine [2].

2.3.5 S – Model

The S curve shows that the pattern of error hours a labor in the unit production of complex from new design [9]:
Equation12

$$T_N = K\,[M + (1 - M)(N + B)^S \quad (12)$$

2.4 Forgetting Curve

Forgetting curve illustrates the memory decrease in unit time. We use Equation 13 to calculate the forgetting curve. Equation 13

$$T_N{}^{LFCM} = K(\theta + N)^s \quad (13)$$

2.5 Prediction

Prediction is a technique used to solve the problems on the production floor. Many researchers propose for the learning curve because it is suitable to predict something on the production floor. Malyusz & Pem[8] managed the labors working time by predicting labor hours needed and the make on-time production scheduling. The learning curve can be used to predict the labor needed by making comparison between stations that have the highest and the lowest learning curves.

3.0 EXPERIMENT

The data collection for the processing time was done at 10 work stations in a glove manufacturing company.

3.1 Data Adequacy Test

The data were taken for 86 times before and after the break at each station. After being tested, all data are considered sufficient, since N '<N.

3.2 Learning Curve at Each Station

Each station is calculated using five existing learning curve models. Then the model with the smallest error value is selected(i.e. B-Standford model or S-model).In this study,the B-Stanford model was selected because it is considered to be more suited to the behavior and character of workers at the time of the observation. Figure 2 is a recapitulation of the learning curve for each work station at the company.

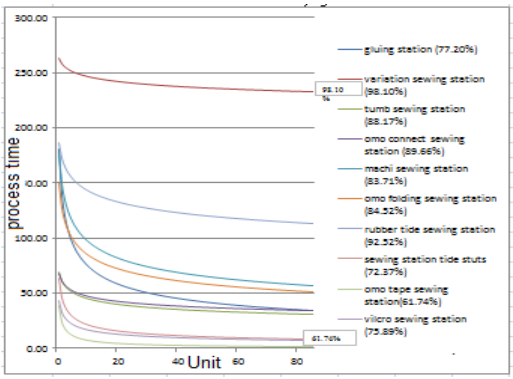


Figure 2 Recapitulation of learning curve at each station

3.3 Learning Curve in the Glove Manufacturing Company

Learning curve is a level of learning for a company. Figure 3 and Table 1 show the sum of learning curve obtained for each station.

Based on Figure 3, the percentage of learning obtained is 91.47% ,by using the B Stanford model. A slope was obtained using the average learning curve data of-0.1286. From the percentage of the learning curve, the maximum output for 2 hours cumulative productive time before the break can be determined.

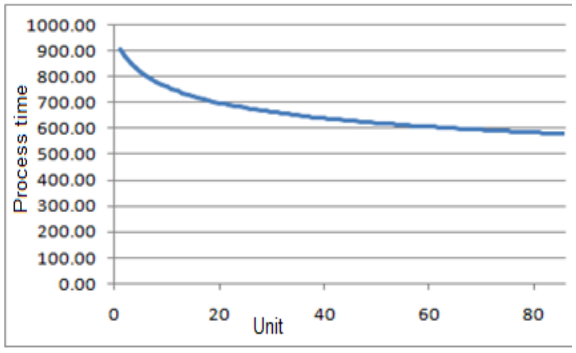


Figure 3 Learning curve in the company

Table 1 2 hours cumulative productivity output before break

No	1	2	3	4	5	6	7	8
LC	906	877	854	835	818	804	791	780

3.4 Forgetting Curve

Forgetting curve in the company is calculated by using the production processing time after the break, and the sum of the learning curves of each work station. The percentage obtained is 91.59%.

From Figure 4 and Table 2, the maximum output for 2 hours of productive time after the break can be calculated.

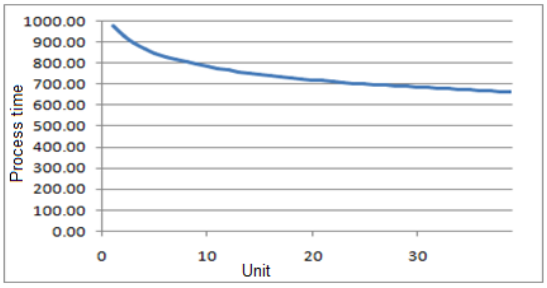


Figure 4. Forgetting curve in the company

Table 2 Two hours cumulative productivity output after break

No	1	2	3	4	5	6	7	8
LC	981	929	895	869	848	831	817	805

3.5 Prediction

Based on Figure 5, one can calculate the amount of the maximum output in the productive hours of company, which is this case, 16 products. From the calculation of the cumulative productive hours, the initial costs of production can be minimized to 15.600 Indonesian Rupiah.

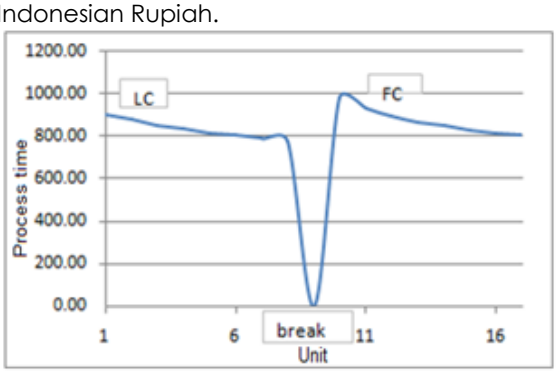


Figure 5 Combination of the learning and forgetting curve

Based on Figure 6, one can perform the labour needs which can be predicted at a particular station by comparing the percentage of the highest and lowest learning curves.

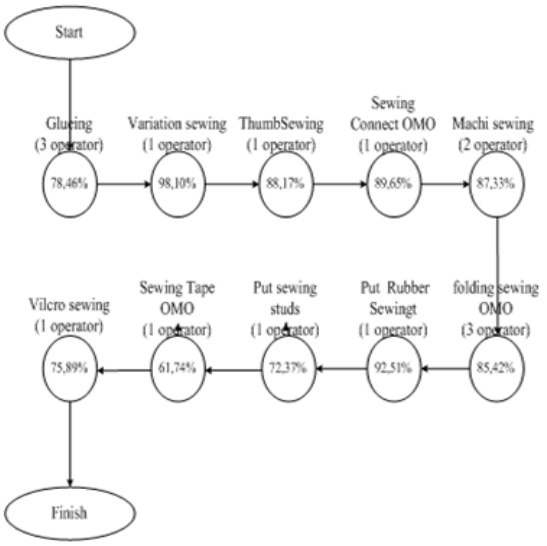


Figure 6 A flow process of company

4.0 RESULT OF LEARNING AND FORGETTING CURVE IN THE GLOVE MANUFACTURINGCOMPANY

The learning curve percentage obtained at the company is 91.47%. The slope value -0.1286 indicates that the pace of learning for the company is high. Then, we obtained a cumulative amount of product produced during two productive hours (7200 seconds) before the break as much as 8 units with a cumulative time of 6668.20 seconds.

The percentage of the forgetting curve obtained at the company is 91.59% with a slope of -0.1266. Based on the above data, we get $\overline{T_1}$ after a break is 981.30 seconds, by using the percentage of the company learning curve which is 91.47%. The N maximum of 8 units was obtained with the estimated time of 6978.88 seconds or approximately 2 hours of production. With that assumption, both models can be used for both the learning curve or forgetting curve.

It can be seen from the comparison between the forgetting and learning curve, that there is a time difference on the resulting total time to complete 8 units due to a decrease time in the forgetting curve of 310.68 seconds. It may be due to the possibility that the operator is experiencing forgetfulness, over the work done previously.

4.1 Prediction

In this research, the needs of employees at the work station with the lowest percentage of learning can be determined, through a comparison of the highest and lowest percentage of work stations. As shown in the above case, the lowest learning curve is available at the omo tape sewing station with the percentage of 61.74%. The learning curve is the highest at the variation sewing station with the percentage of learning at 98.10%. For the omo tape sewing station the difference of the initial processing time with the unit process time is 1.77 seconds with 1 operator. Meanwhile, sewing variations stations have the difference of the initial processing time with the unit process time 2.54 second with 1 operator. It means the operators on the sewing variations station have a bigger increase in learning. Based on the analysis of the difference in the comparison between the two periods, it was found that the omo tape sewing station requires the addition of 1 operator in order to balance the learning speed of labor at the variation sewing station. If the learning speed increases, then the percentage of learning at the station will increase as well.

To avoid the occurrence of additional costs, the more effective and efficient measure is to allocate labor from the omo folding sewing station to the omo tape sewing station. The assumption that the omo folding station has the highest percentage of 85.42% with the largest numbers of three operators can be seen in Figure 6. Thus, it can be concluded that the station is more potential in terms of the allocation of labor from other stations. After the allocation of an operator, the percentage of the learning curve omo tape sewing station has increased from 1.89% to 63.63% without reducing the percentage of the learning curve at the omo folding sewing station (i.e. 85.42%).

5.0 CONCLUSION AND SUGGESTION

The results of the learning curve percentage by the company is 91.47%, the gluing station 78.46%, variation sewing station 98.10%, thumb sewing station 88.17%, omo connect sewing station 89.65%, machi sewing station 87.33%, omo folding sewing station 85.42, rubber tide sewing station 92.51%, sewing station tide studs 72.37%, omo tape sewing station 61.74%, vilcro sewing station 75.89%, respectively. The lowest learning at the omo tape sewing station is 61.74% and the highest learning on the variations sewing station is 98.10%, the percentage of the forgetting curve in the company is 85.42%

The initial cost of production can be minimized to 15.600 Indonesian Rupiah. The needs to add 1 operator to the number of labor, is predictable on the omo tape sewing station, because they have the lowest percentage of learning. It was done by allocating 1 operator from the omo folding sewing station to the omo tape sewing station.

With the research done, it would be proper if the learning curve is also developed with other models so that it can be used in the future for more complex cases with more diverse data. An analysis must be conducted for other problems at the company's production floor through a learning curve. It aims to find out other problems that could be solved by using a learning curve.

Acknowledgement

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