Application of Time Study Model in an Oil Palm Processing Company: A Case Study

A.O. Odior

Department of Production Engineering, University of Benin, Benin-City, Nigeria.

ABSTRACT

This paper presents a case study in the development and application of a time study model in an oil palm processing company. The organization engages in the production of edible palm oil through the introduction of palm butches into the production process. The palm butches move through a series of processing stages to obtain the edible palm oil. These stages include; bunch reception, bunch sterilization, bunch threshing, fruits digestion, pulp pressing, oil clarification and drying of oil which is followed by oil storage and palm kernel recovery.

The study reveals that the time it takes to produce a unit of product is directly proportional to the number of production stages involved and the time spent at each of these production stages. This time is represented by structural equations which are characteristics of the system being studied.

(Keywords: edible palm oil, bunch reception, fruits, digestion, pulp pressing, production stages, food processing)

INTRODUCTION

Time study is a branch of work study which incorporates a range of concerns, including the definition and management of work. It involves a technique of work measurement which is aimed at assessing human effectiveness thereby making possible improved planning and control manning as a basis for sound incentive schemes for higher productivity. Although research on work measurement has evolved in a scientific and rigorous fashion based on the early work of Gilbert and others, the quantitative mathematical modeling of production activities in terms of time study has not evolved in a similarly rigorous fashion (Barnes, 1980; Karger and Bayha 2003). In recent years, the manufacturing organization used as the case study in this work has realized that scientific approaches could be developed to aid dispute settlement between the employees' association of the company and management regarding issues of productivity. In order to achieve this, the company was motivated to approach a management consultant (Oke, 2006).

This paper is an attempt to present the methodology used in solving the productivity issues in an oil palm producing company. The oil palm producing company is located in Edo State, Nigeria. The company is involved in the purchasing of the oil palm butches which are transported to the company site for the crude oil palm processing activities.

The oil palm (*Elaeis guinensis*), is a tropical plant crop and a native of West Africa. Its processing has been an age long industry. It is either processed manually or mechanically. There are about 2.1 million hectares of wild oil palm plantations, 105,000 hectares of small holder plantations, and 82,209 hectares of estate plantations in the country. With these and the projected expansion of about 205,000 hectares, the oil palm will remain the major source of edible oil in Nigeria, and over 80% of palm oil and palm kernel in the country are produced by small scale processors whose capacities vary from a few hundred kilograms to about 8 metric tons per day (Ilechie, 1993).

The oil palm exists in a wild, semi-wild, and cultivated state in the three land areas of the equatorial tropics: Africa, South-East Asia, and America (Hartley, 1988).

Oil palm is the highest yielding of all the oil bearing plants and the spread of the oil by seed may be through the agency of gravity and water, of animals, or of man. The movement by gravity and water is of limited occurrence especially as the fruit does not float (Opeke, 1987). Oil palm has been classified into three major categories, the dura-shell, which consists of medium messocarp content; the tenera which possesses thick mesocarp; and the pisifera, which consists of small pealike kernel in fertile fruits (Purseglove, 1972).

In the operation of the activities of the oil palm processing company, the production manager interacts with the marketing department which, in turn, interacts with the finance department while the finance department then interacts with the purchasing department and the with the production manager. This is shown in Figure 1.

The basic activities in the oil palm production process include the following stages depicted in Figure 2.

THE TIME STUDY MODEL

The major activities in oil palm processing were studied in order to have a background understanding of the production problem, its formulation, and solution. From the information obtained at the company floor, the production system is effective. It infers that there are not many losses or leakages in the production system. Thus, all the effort put into the production system would yield the desired results.

The second type of information obtained from the production system is that the right caliber of production personnel is involved. A third information category is that there is a defined responsibility for each production worker. Thus, a production target is in place and could be monitored.

The fourth information category is that the machines are always available in a ready state. However, it is assumed that whenever a machine breaks down, it can always be repaired and restore in a negligible time frame. The process of producing edible palm oil is clearly divided into stages as given in Figure 2.

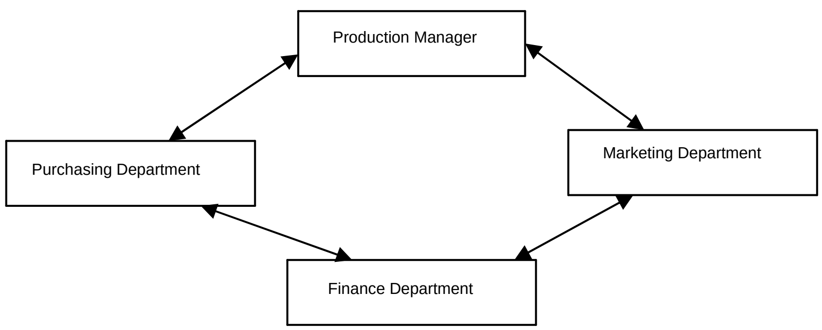

Figure 1: The System Concept for the Manager.

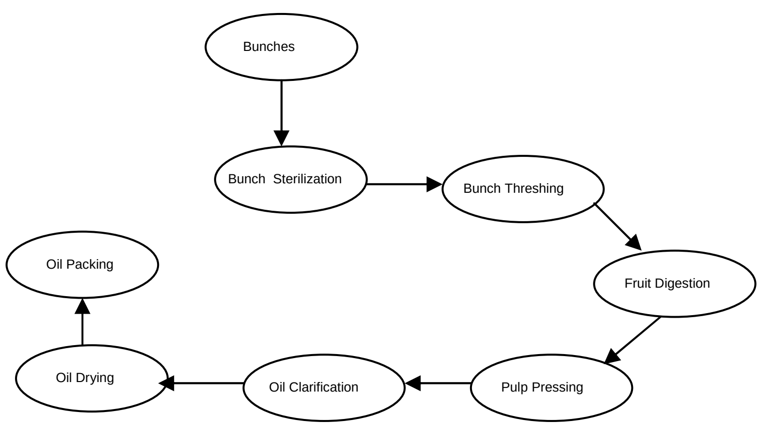

Figure 2: Basic Activities in Palm Oil Production

The first mathematical expression for the model framework is as follows:

$$t = \sum_{j=1}^{n} t_j \qquad \textbf{(1)}$$

where (t) represents the total time used in producing a unit of product.

The variable (j) represents the various workstations of interests, (i.e. bunch reception, bunch sterilization, bunch threshing, fruits digestion, pulp pressing, oil clarification, oil drying, and oil storage).

With close observation of the various workstations, there are variations in the rate of working for both the individuals at the workstations and the machines doing the actual operation. Therefore, we introduce the rate of working for both the machines at the various workstations and the workers as differentials that are expressed mathematically. For instance, if machine j is represented as m_i where m_i may be m_1 for the machine that does the work such as bunch sterilization station, m_2 is the machine that does the work at bunch threshing station, etc.).

If the time taken by the 'in-process' product is time t, then mathematical expression becomes;

$$\frac{dm_j}{dt},$$

Also, if (w_j) represents the human worker at workstation (j), and this worker works for a period of time t units, then we can express the rate of working of this worker as:

$$\frac{dw_j}{dt}$$

Since in time study activities a provision of allowance is always very necessary, we now introduce a parameter 't_a' into the model.

Therefore, the general mathematical expression for the production time t_j at each workstation is given as;

$$t_j = \frac{dt}{dm_j} x \frac{dt}{dw_j} \text{ x } f(x_j) + t_a \qquad \textbf{(2)}$$

where x_j is a normalizing function which converts the expression into time units.

Substituting Equation 2 into Equation 1 gives the following equation:

$$t = \sum_{j}^{n} \left(\frac{dt}{dm_j} x \frac{dt}{dw_j} \text{ x } f(x_j) + t_a\right) \qquad \textbf{(3)}$$

$$= \sum_{j}^{n} \left(\frac{dt}{dm_j} x \frac{dt}{dw_j} x f(x_j)\right) + \sum_{j}^{n} t_a \qquad \textbf{(4)}$$

but $\sum_{j}^{n} t_a = nt_a$

$$\therefore t = \sum_{j}^{n} \left(\frac{dt}{dm_j} x \frac{dt}{dw_j} x f(x_j)\right) + nt_a \qquad \textbf{(5)}$$

we will assume that the rate at which machines are producing and the working rate of workers is constant. Thus Equation 5 becomes;

$$\left(\frac{dt}{dm_j} x \frac{dt}{dw_j}\right) \sum_{j}^{n} f(x_j)) + nt_a$$

We generalize the model by taking $f(x_j)$ as:

$f(x)$, $\frac{dt}{dm_j}$ as $\frac{dt}{dm}$ and $\frac{dt}{dw_j}$ as $\frac{dt}{dw}$.

$$\text{Thus, } t = \frac{dt}{dm} x \frac{dt}{dw} \int_{1}^{n} f(x)dx + nt_a \qquad \textbf{(6)}$$

Assuming that the total number of products produced is denoted by symbol (y), while T is the total time spent for all the products, Equation 7 above becomes,

$$T = yt = y\left(\frac{dt}{dm} x \frac{dt}{dw} \int_{1}^{n} f(x)dx + nt_a\right) \qquad \textbf{(7)}$$

Equation 8 is the general formula for the total time spent in producing y products.

Raw Materials and Electricity Supply

Consider the issue of unavailability of raw materials which are the fresh palm fruit bunches and irregular electricity supply and assuming that $f(x_j)$ is a function of these two parameters of indices such that we have $f(x_j)$ and f(x, z). Therefore Equation 7 can now be expressed as follows:

$$T = yt = y\left(\frac{dt}{dm} x \frac{dt}{dw} \int_1^n f(x,z)dxdz + nt_a\right) \quad \textbf{(8)}$$

This equation gives the real general formula for the total time spent in producing y products.

APPLICATION OF MODEL AND DISCUSSION

This study, which is a case study of an oil palm processing company, is a real life situation of a production company in Edo State of Nigeria. However, the name of the company has been changed to Edible Oil Company to protect the identity of the company. The company specializes in producing different grades of edible oil and palm kernels.

Edible Oil Company is a large production company with a capacity of 92 workers. The company has different types of machines and other facilities for its production. The basic products of the company are, edible oil, palm kernels, and fertilizer. The company operates a nine hours daily production cycle. However, during festive periods such as Christmas, a large number of customers usually patronize the company's products resulting in huge spike sales. This sometimes, leads to increase in the daily working hours of operation.

If the electricity unavailability index and the unavailability of raw materials are defined by functions f(*x*) and f(*z*), then $f(x_j)$ is given as a function of (x) and (z). Also, $f(x_j)$ = f(x, z).

Assuming that the electricity supply index (x) obeys a linear function such as 2x + 5, then the expression is now f(x) = 2x + 5. From the above equations, we know that (n) is the number of workstations while (t_a) is the time allowance. From the actual production observation, the mathematical model that fit the time problem in terms of number of machines is:

$$t = mx^3 + m^2x^2 + x \quad \textbf{(9)}$$

Differentiating Equation 9 gives:

$$\frac{dt}{dm} = x^3 + 2mx^2 \quad \textbf{(10)}$$

Also, the mathematical expression that represents time with respect to the number of workers is:

$$t = wx^3 + w^2x^2 + x \quad \textbf{(11)}$$

Differentiating above gives:

$$\frac{dt}{dw} = x^3 + 2wx^2 \quad \textbf{(12)}$$

Note that (n) has been stated earlier as the number of workstations, and (t_a), the time allowance. If 1,200 products are produced by the company for 0.75 second per unit product, then:

t_a = 1,200 x 0.75 seconds.

Therefore t_a = 900 seconds.

Given that n = 8 and from Equation above, we have:

$$t = t_j = \frac{dt}{dm} x \frac{dt}{dw} \int_1^n f(x)dx + nt_a.$$

But $\frac{dt}{dm} = x^3 + 2mx^2$ and $\frac{dt}{dw} = x^3 + 2wx^2$

There are 8 workstations for the palm oil production processes, hence n = 8. From Equation 6, we can now estimate the values. We know that,

$$t = t_j = \frac{dt}{dm} x \frac{dt}{dw} \int_1^n f(x)dx + nt_a$$

and the values of $\frac{dt}{dm}$ as $x^3 + 2mx^2$

and $\frac{dt}{dw}$ as $x^3 + 2wx^2$,

with n = 8 and t_a = 140 seconds.

The average period electricity fails in a day is 45 minutes, while the average daily working time is 9 hours.

Note that x is the ratio of the period when electricity fails in a day to that of the working hours for that same day.

Thus, x = $\frac{45 \min utes}{9x60 \min utes} = \frac{45}{540}$ = 0.0833.

This gives an index value of 0.0833.

Note that the number of machines m = 6, number of workers w = 92. Then since f(x) = 2x + 5, we now evaluate the function by substituting into Equation 6 as follows:

$$t = \frac{dt}{dm} x \frac{dt}{dw} \int_1^n f(2x+5)dx + nt_a$$

$$\text{so } t = \frac{dt}{dm} x \frac{dt}{dw} (x^2 + 5x + c) + nt_a$$

Note that at the start of production process, all the factors are zero since no product has been produced. This gives the production constant c to be zero.

$$\therefore t = \frac{dt}{dm} x \frac{dt}{dw} (2x+5) + nt_a \quad \textbf{(13)}$$

Now substituting the required values into the equation gives:

$$t = t_j = (x^3 + 2mx^2)(x^3 + 2wx^2)(x^2 + 5x) + nt_a \quad \textbf{(14)}$$

$\therefore$ t = $(0.0833^3 + 2 \text{ x } 6 \text{ x } 0.0833^2)$ x
$(0.0833^3 + 2 \text{ x } 92 \text{ x } 0.0833^2)$ x
$(0.0833^2 + 5 \text{ x } 0.0833)$ +
(8 x 900) seconds. = 7200.04535 seconds.

$\therefore$ t = 2.00 hours.

Note that t_j = 0.75 second per unit product, therefore the total products produced in 2.00 hours is:

$$\frac{2.00 \text{ hours}}{0.75 \text{ second per unit product}}$$

$$= \frac{2.00 \text{ x } 3600 \text{ seconds}}{0.75 \text{ second per unit product}}$$

= 9,600 units of product.

That is 9,600 units of product would be produced in 2.00 hours.

In conclusion, we have therefore been able to apply a time study mathematical model in calculating the time required for operational activities in the production processes for edible palm oil and it is seen that 9,600 units of edible palm oil could be produced in two hours.

CONCLUSION

The production of edible palm oil by the company studied has been thoroughly examined. It has been observed that setting standards in the achievement of production targets is very important and one of the techniques for achieving this aim is the application of time study models in the monitoring and control of employees on the production floor. In this paper therefore, the time study concept in the production process of edible oil palm production is modeled mathematically in order to analyze the production activities of the company.

The mathematical model was developed with the application of differential calculus to the elements of the production systems that have significant effects on the production output from the system. One observed that our current model is quite different from the previous models in the sense that it incorporates some uncontrollable factors such as irregular supply of electricity, unavailability of raw materials, as well as excessive machine breakdowns due to old age. The study is however considered to be very beneficial to practicing managers in the industries and is therefore recommended for use.

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