GLOBAL JOURNAL OF ENGINEERING RESEARCH VOL 7, NO. 1, 2008: 15 - 19
 ISSN 1596-292X

A CASE STUDY APPLICATION OF TIME STUDY MODEL IN PAINT MANUFACTURING COMPANY

A. O. ODIOR

(Received 15, January 2008; Revision Accepted 26, March 2008)

ABSTRACT

This paper presents a case study in the development and application of a time study model in a paint manufacturing company. The organization specializes in the production of different grades of paint and paint containers. The paint production activities include; weighing of raw materials, drying of raw materials, dissolving of raw materials, material filtering, material stirring, product inspection and quality control and product packaging. The processes in paint container production comprise of cutting of sheet metal, sheet metal rolling, sheet metal pressing for overlapping hook, cutting of top cover, cutting of bottom cover, coiling of sheet metal to shape, pressing bottom cover to position.

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

KEYWORDS: Paint Production, Time Study Model, Paint Container and Product Inspection.

1.0 INTRODUCTION

Most manufacturing organizations have realized that scientific approaches could be developed to aid dispute settlement between the employees' association of the company and management regarding issues of productivity. Time study is one of the techniques used in solving productivity problems in such manufacturing companies. Time study is a technique of work measurement designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance and research on time study incorporates a range of concerns, including its definition and management (Edo *et al.*, 2001; Worrall and Smith, 1985; Watson, 1988; Aft, 2000). Although research on work measurement has evolved in a scientific and rigorous fashion, based on 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; Oke, 2006; Karger and Bayha; 2003).

Paint is defined as a fluid or semi – fluid material which may be applied to a surface in relative thin layers and which changes to a solid, may or may not be reversible and may occur by evaporation of solvent or by chemical reaction or by a combination of the two. It usually consists of a binder or a pigment which contributes opacity, colour, hardness and a solvent or thinner which controls the consistency. In 1500 BC, the Egyptians developed the art of painting using a wide number and variety of colours. They also discovered the present day vanishes using naturally occurring resins as their film forming ingredient. (Yugbovwre, 1995).

Cowries Paint Nigeria Limited is a company which specializes in the production of different grades of paint and paint containers. An important problem faced in the paint production system is that of determining the time it takes to produce a unit product. In order to thoroughly analyze the problem, the production processes for each of the products produced by the company were examined. Paint production activities could be broken down into seven activities; weighing, drying, dissolving of raw materials, material filtering, material stirring, product inspection and quality control and product packaging. In the production of paint container, six steps are involved; cutting of sheet metal, sheet metal rolling, sheet metal pressing for overlapping hook, cutting of top and bottom cover, coiling of sheet metal to shape, pressing bottom cover to position.

2.0 DEVELOPMENT OF THE TIME STUDY MODEL

Some information needs to be declared in order to have a thorough understanding of the problem in the paint manufacturing company, its formulation, and solution. This is very necessary for us to develop the model which is intended to serve as a guide to other practicing managers in manufacturing systems, who are willing to apply the model. The necessary information were obtained at the factory floor, and it was discovered that the production system is effective.

In the operation of the activities of the paint manufacturing 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, who then interacts with the production manager This is shown in Figure 1.

A. O. Odior, Department of Production Engineering, University of Benin, Benin – City, Nigeria

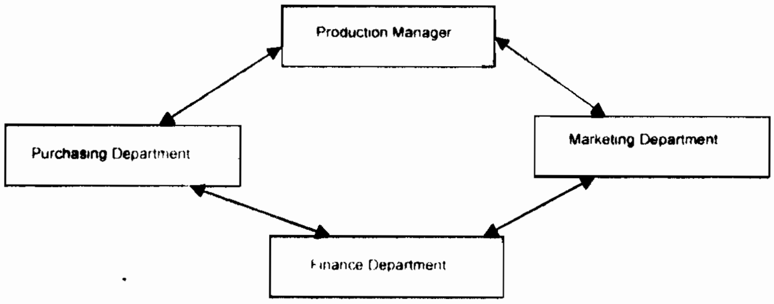

Fig. 1: The System Concept for the Manager.

The production of paint by Cowries Paint Company involves two major stages: the first stage is the production of liquid paint while the second stage involves the production of paint containers. The basic stages in paint production by Cowries Paint Company are shown in Figure 2, while the various stages in paint container production by the company are shown in Figure 3

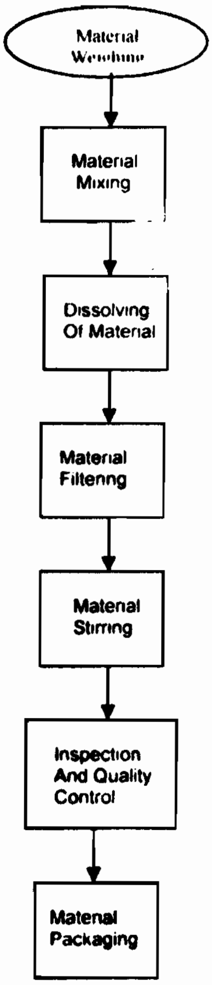

Fig. 2: The Basic Activities in Paint Production.

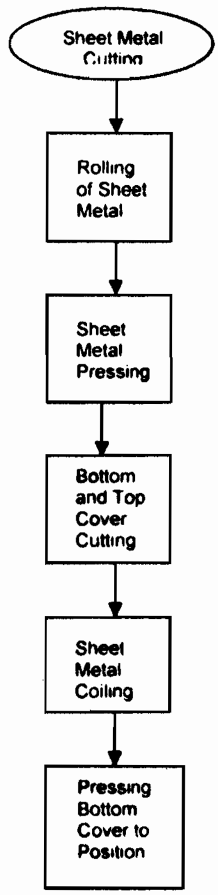

Fig. 3: The Basic Activities in the Production of Paint Container.

3.0 THE TIME STUDY MODEL

The major activities in paint production were studied in order to have a background understanding of the problem, its formulation and solution. From the information obtained at the company floor, the production system is effective. It infers that no much 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 calibre 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 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 restored in a negligible time frame.

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

$$t = \sum_{i=1}^{n} t_i \quad \text{------------------ 1}$$

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

The variable (i) represents the various workstations of interests, (i.e. weighing and drying of raw materials, mixing of raw materials, dissolving of raw materials, material filtering, material stirring, inspection and quality control and product packaging). 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 i is represented as m_i where m_i may be m_1 for the machine that does the work such as weighing and drying of raw materials station, m_2 is the machine that does the work at mixing of raw materials station, etc.).

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

$$\frac{dm_i}{dt}.$$

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

$$\frac{dw_i}{dt}$$

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_i at each workstation is given as;

$$T_i = \frac{dt}{dm_i} x \frac{dt}{dw_i} x\, f(x_i) + t_a \quad \text{-------------------- 2}$$

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

Substituting Equation 2 into Equation 1 gives the following equation

$$t = \sum_{i}^{n} \left(\frac{dt}{dm_i} x \frac{dt}{dw_i} x\, f(x_i) + t_a \right) \quad \text{--------- 3}$$

$$= \sum_{i}^{n} \left(\frac{dt}{dm_i} x \frac{dt}{dw_i} x f(x_i) \right) + \sum_{i}^{n} t_a \quad \text{------------- 4}$$

$$\text{but } \sum_{i}^{n} t_a = nt_a$$

$$\therefore t = \sum_{i}^{n} \left(\frac{dt}{dm_i} x \frac{dt}{dw_i} x f(x_i) \right) + nt_a \quad \text{------------ 5}$$

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

$$\left(\frac{dt}{dm_i} x \frac{dt}{dw_i} \right) \sum_{i}^{n} f(x_i)) + nt_a$$

We generalize the model by taking $f(x_i)$ as $f(x)$, $\frac{dt}{dm_i}$ as $\frac{dt}{dm}$ and $\frac{dt}{dw_i}$ as $\frac{dt}{dw}$.

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

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,

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

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

3.1 RAW MATERIALS AND ELECTRICITY SUPPLY

The issue of unavailability of raw materials and irregular electricity supply is to be considered and assuming that $f(x_i)$ is a function of these two parameters of indices such that we have $f(x_i)$ and f(x, z). Therefore Equation 7 can now be expressed as follows:

$$T = yt =$$

$$y\left(\frac{dt}{dm} x \frac{dt}{dw} \int_{1}^{n} f(x,z) dx dz + nt_a \right) \quad \text{----- 8.}$$

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

4.0 DISCUSSION

This study which is a case study of a paint manufacturing company, is a real life situation of Cowries Paint Company located in Edo state of Nigeria. The company specializes in the production of different grades of paint and paint containers with a capacity of 72 workers. The company has different types of machines and other facilities for its production. The basic products of the company are emulsion paint, gloss paint and paint containers, and the company operates a ten hours daily production cycle.

For the application of the model to our study the electricity unavailability index and the unavailability of raw materials are defined by functions f(x) and f(z) then $f(x_i)$ is given as a function of (x) and (z). And so, $f(x_i)$ = f(x, z).---------------------9

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:

$$t = mx^3 + m^2x^2 + x \text{ ------------------10}$$

Differentiating Equation 10 gives:

$$\frac{dt}{dm} = x^3 + 2mx^2 \text{ ....11}$$

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

$$t = wx^3 + w^2x^2 + x \text{ ------------------------- 12}$$

Differentiating above gives:

$$\frac{dt}{dw} = x^3 + 2wx^2. \text{ ------------------------13}$$

Note that (n) has been stated earlier as the number of workstations, and (t_a), the time allowance. If 2,800 products are produced by the company for 0.5 second per unit product, then

t_a = 2,800 x 0.5 seconds.

Therefore t_a = 1,400 seconds.

Given that n = 7 and from Equation above, we have

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

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

There are 7 workstations for the paint production processes, hence n = 7. From equation 6, we can now estimate the

values. We know that $t = t_i = \frac{dt}{dm} x \frac{dt}{dw} \int_1^n f(x)dx + nt_a$

and the values of $\frac{dt}{dm}$ as

$x^3 + 2mx^2$ and $\frac{dt}{dw}$ as $x^3 + 2wx^2$, n = 7 and

t_a = 1,400 seconds.

The average period electricity fails in a day is 95 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.

$$\text{Thus, } x = \frac{95 \text{ minutes}}{9x60 \text{ minutes}} = \frac{95}{540} = 0.1759.$$

This gives an index value of 0.1759.

Note that the number of machines m = 5, number of workers w = 126. Then since f(x) = 2x + 5, we now evaluate the function by substituting into Equation 6 as follows;

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

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

were c is the production constant.

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.

$$\therefore t = \frac{dt}{dm} x \frac{dt}{dw} (x^2 + 5) + nt_a \text{ -----------------14}$$

Now substituting the required values into the equation gives:

$$t = t_i = (x^3 + 2mx^2)(x^3 + 2wx^2)(x^2 + 5x) + nt_a$$

----------15

$\therefore t = \{(0.1759^3 + 2 \times 5 \times 0.1759^2)(0.1759^3 + 2 \times 126 \times 0.1759^2)(0.1759^2 + 5 \times 0.1759)\}$

+ (7x1400) seconds. = 9802.2366 seconds.

$\therefore t$ = 2.7228 hours = 2 hours 43 minutes.

Note that t_i = 0.5 second per unit product, therefore the total products produced in 2 7228

$$\text{hours} = \frac{2.7228 \text{ hours}}{0.5 \text{ second per unit product}}$$

$$= \frac{2.7228 \times 3600 \text{ seconds}}{0.5 \text{ second per unit product}} = 19.604.16$$

units of product.

That is 19,604 units of product would be produced in 2 hours 43 minutes.

In conclusion, we have therefore be able to apply a time study mathematical model in calculating the time required for operational activities in the production processes for the manufacture of paint and it is seen that 19,604 units of paint could be produced in two hours forty three minutes.

4.1 Observations

The impact of setting standards in the achievement of production targets in paint production by the paint manufacturing company has not been given a thorough consideration until this current study. The company however realized that one of the approaches in achieving this aim is the application of time study models in the monitoring and control of employees on the production floor. It was observed that the current model is slightly different from previous models in the sense that it incorporates some uncontrollable factors such as irregular supply of electricity, unavailability of raw materials, excessive and frequent machine breakdown due to old age, etc. All of these factors have been considered to have a positive impact on the model.

5.0 CONCLUSION

The production of paint emulsion and gloss as well as the paint containers by the company studied has been thoroughly examined. It has been observed that the setting of 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 a paint production process is modeled mathematically in other 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 effect on the production output from the system. Our model incorporates some uncontrollable factors such as irregular supply of electricity, unavailability of raw materials as well as excessive machine breakdown 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.

REFERENCES

Aft, L.S. 2000. Work Measurement and Methods Improvement. John Wiley and Sons. ISBN: 0471370894.

Barnes, R.M. 1980. Motion and Time Study: Design and Measurement of Work. John Wiley and Sons 7th edition. ISBN: 0471059056.

Edo, M., Evans, T.D., and Viengkham, O.V. 2001. "Study on Structure and Time of Assembly Motion from a Viewpoint of the Motion Velocity". Bulletin of the College of Engineering, Forest Ecology and Management. New York.

Karger, D. W. and Bayha, F. H. 2003. Background and Foundations of Work Measurement. Industrial Press. 4th edition. ISBN: 0831111704.

Oke, S.A. 2006. "A Case Study Application of Time Study Model in an Aluminum Company". Pacific Journal of Science and Technology. 7(2):153-162.

Watson, I. J., 1988. Electronic Time Study. Colliery Guardian. 236(5):144.

Worrall, B.M. and Smith, M.D. 1985. Application of Computerized Time Study to Establish Time Standards. Springer-Verlag: Berlin. pp. 745-750

Yugbovwre, U. M., 1995. Analysis of the Production Line for the Manufacture of Different Types of Paint. B.Eng. Thesis, Univ. Benin, Nigeria, 67pp.