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APPLICATION OF TIME STUDY MODEL IN A RICE MILLING FIRM: A CASE STUDY

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Abstract : This paper presents a case study in the development and application of a time study model in a rice milling firm. Rice milling is a process whereby the rice grain is transformed into a form suitable for human consumption and it has to be done with utmost care to prevent breakage of the kernel and improve the recovery. Rice is a very important nutritional diet for over half the world's population and as a result rice milling firm has occupied a significant position in small, medium and large scale enterprises of many nations.

The study reveals that the time it takes to mill a 50 kilograms bag of rice 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 rice milling firm being studied.

1.0: INTRODUCTION

Rice milling is a process which involves the removal of the trash and then the husk from the rice, milling the bran off of the endosperm to get the white rice and final removal of broken kernels and other defects. Most rice varieties are composed of roughly 20% rice hull, 11% bran layers, and 69% starchy endosperm, also referred to as the total milled rice. Total milled rice contains whole grains or head rice, and broken rice, while the by-products in rice milling are rice hull, rice germ and bran layers, and fine broken rice, (Autrey, et. al., 1955). Rice kernel is covered by two layers: the most outer layer which is called the husk (hull) and the inner one called bran. The whole rice kernel before removing these layers is called the paddy (rough rice), (Davis, 1944). The husk and bran are not eatable; therefore, they must be removed from paddy. Husk is not tightly stuck to the kernel, so it is easily removed from the kernel to get brown rice. The bran is more difficult to be removed from brown rice, because it is tightly attached to the kernel and the process by which the bran is removed from brown rice is called whitening or pearling process, (Clement and Seguy, (1994). During this process, the rice kernels are subjected to an intensive mechanical and thermal stresses which cause some damage to the rice kernels and break some of them (Matthews et al., 1970). Rice kernel breakage during the milling process is affected by different parameters such as paddy harvesting conditions, paddy drying, physical properties of paddy kernels, environmental conditions, and type and quality of milling system components, (Davis, 1944; Pominski et al., 1961).

Rice is a well-known cereal grass plant (Oryza sativa) which is extensively cultivated in warm climates, and the grain forms a large portion of the food of the inhabitants. Rice from the field, is usually harvested at about 18% to 24% moisture and must be dried down to about 12%

Keywords : Time Study Model, Rice Milling, Rice Grain, Nutritional Diet.

to 14% so that it can be safely stored ((Piggott, et. al., 2007). In most developing countries rice is somehow air-dried and the straw and rice can be dried in the field. It is sometimes stacked in a special manner to allow air to pass through it and cause rain run off quickly. Most often, the paddy rice is spread on some sort of concrete or pavement and raked over until dry and in some developing countries, you will see rice drying all over the roads during harvest season (Budhu, M. (1971). In developed countries, rice is dried in farm storage bins that have air chambers underneath that force air to pass up through the rice, or rice is dried in large column dryers where the rice makes two to five passes through the dryer in a continuous flow type system (Piggott, et. Al., 2007). Drying of the rice even while in the field prior to harvest, is a critical component in regards to quality. Rice that is cracked during drying will have a lower percentage of head yield and will have a poorer quality after cooking. A rice milling system can be a simple one or two step process, or a multi stage process. In a one step milling process, husk and bran removal are done in one pass and milled or white rice is produced directly out of paddy. In a two step process, removing husk and removing bran are done separately, and brown rice is produced as an intermediate product, while in multistage milling, rice will undergo a number of different processing steps ((Piggott, et. Al., 2007).

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 ai, 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)

2.0: OPERATIONS OF RICE MILLING FIRM

The basic activities in rice milling operation include: clearing, hulling, milling, polishing, grading, sorting and pack/storage which are presented in Table 1.

Table-1 : Key to The Various Unit Operations

Unit operation	Purpose
Clearing	Removes foreign objects, such as hey, stone, tree stump, from the paddy rice.
Hulling	Rubs excessive husks off cleaned paddy. On removal, brown rice is separated from the husks though ventilation process and mechanical equipment leaving pure brown rice available for milling.
Milling	The milling, or whitening, stage removes the bran layer from brown rice. The modem multi-break, vertical whiteners use both abrasion and friction to gently and efficiently convert brown rice to milled white kernels. The bran layer is by air ventilation, which sucks in the brand layer process usually takes 2 to 3 cycles, depending on the required milling degree.
Polishing	Smoothing and brightening a surface of rice grain by a roll or series of rolls.
Grading	Separates milled rice (mixture of different sizes: Whole grain, head rice, and broken rice) by a sieve grader include several sizing techniques.
Sorting	Removes rice defects, such as discolorations, yellows, immatures (green), chalky, peck, seeds, red rice, glass, stones. Add value to white rice, parboiled rice to ensures that only the cleanest rice is passed.
Pack / Storage	The finished rice will be packed and stored in individual bads, according to its grade, and the rice is ready for delivery to customers.

2.1: By-Products of Rice Milling Firm

In rice milling, some of the grains are normally broken, these have been used to make rice flour, rice wines and beer, rice curls and cakes. In addition, rice makes delicious cakes, pastries, cereals and tasty snacks such as rice crispies. Other by product utilization of rice include: rice hull, rice bran, rice polish, rice straw etc.

3.0: THE TIME STUDY MODEL

The basic activities in oil palm processing were studied in order to have a background understanding of the problem, its formulation and solution. From our study, it was discovered that the production system is effective as there were no much losses or leakages in the production system. Thus, all the effort put into the production system would yield the desired results. There is a defined responsibility for each production worker at each of the various stages of operation. Thus, a production target is in place and could be monitored. 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 process of milling consumable rice is clearly divided into different stages as given in Figure–1.

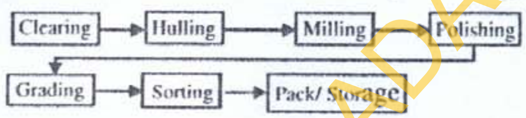

Fig-1 : Summary Chart for Rice Milling Process.

The first mathematical expression for our time study model framework is as follows :

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

where (t) represents the total time used in producing a unit of product and n is the number of workstations. The variable (j) represents the various workstations of interests, (i.e. clearing, hulling, milling, polishing, grading, sorting and pack/storage). The study reviewed 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 where m may be m for the machine that does the work such as clearing of rice, m is the machine that does the work at rice hulling station, while m is the machine that does the work at rice milling station, etc)

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

$$\frac{dm_j}{dt} \text{ for machines}$$

$$\text{and } \frac{dw_j}{dt} \text{ for workers}$$

where

m_j represents the machine performing operation at workstation station (j), working for a period of time t units.

W_j represents the human worker at workstation (j), and this worker works for a period of time t units.

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;

$$t_j = \frac{dt}{dm_j} * \frac{dt}{dw_j} * f(x_j) + t_a \quad (2)$$

where x_j is a normalizing function which converts the expression into time units. Substituting Equation 2 into Equation 1 gives the following equation.

$$t = \sum_j^n \left\{\frac{dt}{dm_j} * \frac{dt}{dw_j}\right\} * f(x_j) + t_a) \quad (3)$$

$$= \sum_j^n \left\{\frac{dt}{dm_j} * \frac{dt}{dw_j}\right\} * f(x_j)) + \sum_j^n t_a \quad (4)$$

but $\sum_j^n t_a = nt_a$

$$\therefore t = \sum_j^n \left\{\frac{dt}{dm_j} * \frac{dt}{dw_j}\right\} * f(x_j)) + nt_a \quad (5)$$

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

$$t = \left\{\frac{dt}{dm_j} * \frac{dt}{dw_j}\right\} \sum_j^n f(x_j)) + nt_a \quad (6)$$

We generalize the model by taking $f(x_j)$ as $\frac{dt}{dm_j}$ as $\frac{dt}{dm}$ and $\frac{dt}{dw_j}$ as $\frac{dt}{dw}$

$$\text{Thus, } t = \frac{dt}{dm} * \frac{dt}{dw} \int_1^n f(x)dx + nt_a \quad (7)$$

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

$$\Re_T = yt = y\left\{\frac{dt}{dm} * \frac{dt}{dw} \int_1^n f(x)dx + nt_a\right\} \quad (8)$$

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

3.1: Raw Materials and Electricity Supply.

Consider the issue of unavailability of raw materials 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:

$$\Re_T = yt = y\left\{\frac{dt}{dm} * \frac{dt}{dw}\int_1^n f(x,z)dxdz + nt_a\right\} \quad (9)$$

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

4.0: APPLICATION OF MODEL AND DISCUSSION

Our study is a real life situation of a rice milling firm located in Nigeria and the name of the company has been changed to rice milling firm to protect the identity of the company. The firm has a capacity of 25 workers with 5 machines performing its operational activities. The basic products of the company are, edible rice, broken rice and rice hulls. 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 an 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 3x + 4, then the expression is now f(x) = 3x + 4. 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:

$$t = mx^3 + m^2x^2 + x \quad (10)$$

Differentiating Equation 10 gives:

$$\frac{dt}{dm} = x^3 + 2mx^2 \quad (11)$$

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

$$t = wx^3 + w^2x^2 + x \quad (12)$$

Differentiating above gives:

$$\frac{dt}{dw} = x^3 + 2wx^2. \quad (13)$$

Note that (n) has been stated earlier as the number of workstations, and (t_a), the time allowance.

If 87 gm of yam flour are produced by the company for 0.056 second per unit product, then we have allowance.

If 45 gm of rice is milled by the company for 0.056 second per unit product, then we have allowance.

If 30.75 gm of rice is milled by the company for 0.50 second per unit product, then $ta = 30.75 \times 0.50$ seconds.

Therefore $t_a = 15.375$ seconds.

There are 7 workstations for the palm oil production processes, hence n = 7. From equation 7, we can now estimate the value from Equation (7):

$$t = t_1 = \frac{dt}{dm} * \frac{dt}{dw}\int_1^n f(x)dx + nt_a$$

But $\frac{dt}{dm} = x^3 + 2mx^2$ and $\frac{dt}{dw} = x^3 + 2wx^2$ (from (11) and (13))

Therefore, equation (7) becomes :

$$t = (x^3 + 2mx^2)(x^3 + 2wx^2)\int_1^4 f(x)dx + nt_a \quad (14)$$

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.

Thus, $x = \frac{95 \text{ minutes}}{9 \times 60 \text{ min utes}} = \frac{95}{540} = 1.7593$

This gives an index value of 1.7593.

Note that the number of machines m = 5, number of workers w = 25.

Then since f(x) = 3x + 4, we now evaluate the function by substituting into Equation (14) as follows;

$$t = (x^3 + 2mx^2)(x^3 + 2wx^2)\int_1^4 f(x)dx + nt_a$$

$$t = (x^3 + 2mx^2)(x^3 + 2wx^2)\int_1^4 (3x + 4)dx + nt_a$$

$$t = (x^3 + 2mx^2)(x^3 + 2wx^2)(3x^2 + 4x + c) + nt_a$$

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

$$t = t_j = (x^3 + 2mx^2)(x^3 + 2wx^2)(3x^2 + 4x) + nt_a \quad (15)$$

$\therefore t = \{(1.7593^3 + 2 \times 5 \times 1.7593^2)(1.7593^3 + 2 \times 25 \times 1.7593^2)(3 \times 1.7593^2 + 4 \times 1.7593) + (7 \times 15.375)\}$ seconds = 64507.318 seconds = 17.918699 hrs

Note that t_j = 0.50 second per unit product, therefore the total products produced in 17.91 8699 hours

$= \frac{17.918699 \times 3600 \text{ seconds}}{0.5 - \text{second / product}} = 129014.636$ units of product

= 129014.636 units of product in 17.918699 hours.

Therefore the total units of product produce in average daily working period of 9 hours

is $= \frac{129014 \times 9 \times 3600 \text{ min utes}}{5.34 \text{ min utes}}$ grams of rice

= 13046423.87 grams of rice

= 13,046 kg of rice.

That is 13,046 kilogram units of rice would be milled in an average daily working period of 9 hours.

In conclusion, we have therefore be able to apply a time study mathematical model in computing the time required for operational activities in the production processes for rice milling and it is seen that 13,046 kilogram units of rice could be milled in nine hours.

5.0: CONCLUSION

The impact of setting standards in the achievement of production targets in rice milling by company studied 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.

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