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OPTIMIZING THE PRODUCTION CAPACITY OF VEHICLE NUMBER PLATE PLANT USING A TIME-BASED MATHEMATICAL MODEL

RICHARD PAUL CHUKWUGOZI

Federal Road Safety Corps, Akure Nigeria
E-mail: richard_78ng@yahoo.com; pc.richard@frsc.gov.ng

ABSTRACT

This paper presents a case study in the development and application of a mathematical model to optimize the production capacity of Number plate plant in Nigeria which is into the production of different grades of Number plates. The motivation of this study was borne out of the need to clearly explain the role of time gap as an impetus for nefarious activities in the Vehicle Number plate production and how it can be tackled using time-based mathematical model. The study reveals that 10000 units of Number plate would be produced in 83.33hrs and there is need to increase the efficiency of the production system to meet up with the drive of sanitizing the motor vehicle administration.

***Keywords**: Number plate, production, time gap and model*

1. INTRODUCTION

Time is an important quantity of measurement in engineering to determine the duration of a particular process. In a production process, 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 those production stages. Time study is one of the techniques used in solving productive problem especially where timeliness is an essential parameter for measuring workers' performance.
Time study is a work measurement technique for recording the time and rates of working for the elements of a specified job carried out under specific conditions and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.

Although research on work measurement has evolved in a scientific and rigorous fashion based on early work of Gilbreths et al, the quantitative mathematical modelling of production activities in terms of time study has not evolved in a similar fashion (Barnes, 1980; Oke, 2006; Kerger and Bayha, 2003, Odior and Oyawale, 2012).
This paper attempted to present a methodology for the production of Vehicle Number plate which involves the basic operations such as blanking, screen printing, embossing, coating, drying, inspection and packaging. There are series of steps involve in the various operations. The production plant in question is found in Lagos while similar ones are found at both Awka and Gwagwalada in Nigeria under the auspice of Federal Road Safety Corps and is into the production of Vehicle Number plates ranging from private to commercial, military, diplomat etc.

Federal Road Safety Corps, a parent organisation is located in Nigeria with Headquarters at Abuja empowered with the design and production of Number plate for all categories of vehicle as entrenched in the FRSC Establishment (Act) 2007. As part of the Corps' comprehensive reform of the licensing scheme, retooled the Vehicle Number Plate Plant in order to strengthen the capability of Number plate as a security document thereby phasing out the obsolete machinery/equipment in the Plant.

An important problem faced in the Vehicle Number plate production systems is that of determining the appropriate time allocation for the different production stages. When time is not taken cognisance of in the production process, demand of Vehicle Number plate would go higher than its

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supply which would give room for racketeering and other sharp practices (parallel production). It is on this basis that the need for appropriate timing for different production stages becomes very imperative.
The study technique was utilized to develop a model for estimating the production capacity of the plant. In order to achieve this, the production processes for the Vehicle Number plate production activities were examined.

2. BRIEF TECHNICAL DESCRIPTION OF NEW VEHICLE NUMBER PLATE

The new Vehicle Number plate has directional watermarked impressions of the 'Coat of Arm' and 'Nigeria' and are security measures which can lower criminal activity (i.e. counterfeiting) related to motor vehicles. These are visible by viewing the Number plate at an angle of 30 degrees in bright sunlight at approximately 2 meters distance. Sizes for the Number plates are: Motor vehicle 6.125" (155.6mm) × 12.125" (308mm) and Motorcycle 4" (101.6mm) × 9.125" (231.8mm).
At the bottom legend of each plate "Federal Republic of Nigeria" is screen printed or pre-printed on the retro-reflective sheeting.
All Private and Commercial fancy numbers are tied to a Local Government Area code screen printed at the top right hand side of the number plates.
The border of plate is flanged and depressed.
Embossed alphanumeric numbering for commercial/private plate has three alphabet code assigned to the local government where the plate is being issued for ease of identification.
2.1 Format: The format of the numbering system is standardized throughout the federation to a maximum of 8.5 alphanumeric characters. These characters can be broken into components indicating specific vehicle number, license area code or authority code.
2.2 Vehicle Number: Maximum of five (5) character alphanumeric number, e.g. 435 AG, 453 SD, noting that 345 AG is for instance, different from 345 GA and AG 345.
2.3 License Area Code: Full three alphabet code e.g. ABC, KMC, JNN, DKA, KWB, etc.
2.4 Authority Code: This applies mainly to Government and Para-Military vehicles. It is three character alphanumeric code e.g. A_1^0 , etc.

2.5 Colour Codes
Motor vehicle number plates are categorized by their colours, thus:
Government – Green lettering on white background
Private - Blue lettering on white back-ground
Commercial – Red lettering on white back-ground
Para (Military) – Black lettering on white background
Diplomatic
White lettering on blue background (Consulates and UN)

3. PLATE PRODUCTION PROCESS

Aluminum substrate is material mainly used for the production of number plate and has a unique advantage being easily manipulated because of its ductile nature. There are four major stages in the production process of Number plate which are explained underneath.

3.1 Blanking

Blanking is the process of cutting blanks to shape of Number plate. Aluminum substrate is used to produce number plate. The components that make up a blanking line are follows:

a. Stock rill -The substrate is mounted on the stock rill and stretched to the brush tank.
b. Brush tank - This is the chamber that washed off the dirt on the substrate.
c. Straightener - This is the chamber that straightens up any rough edges or contours on the substrate and then feed the substrate to the applicator.
d. Applicator - This is the machine that applies the sheeting that has logo of Nigeria on the smooth side of the substrate.
e. Blanking press - this is the machine that will now cut the substrate to size of number plate plain blanks.

3.2 Screen Printing

Screen Printing Section - This is the section that deals with writing of state name and slogan plus the Federal Republic of Nigeria on the plain blanks. The work here start with production of mesh using Aq_2 and sensitizer, after this the state name and slogan is exposed

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on the mesh using the expolite machine at the dark room and the mesh is wash off using the high pressure ash machine at the washing area. After this, the mesh is fixed on the cameo 18 screen printing machine, screen printing ink is poured on the mesh, then the blanks (a pair) is set on the machine and leg pedal is pressed so that the character of the state name is transferred to the blanks. The blanks are now kept on the conveyor belt of the curing machine to dry.

3.3 Embossing

Embossing Section - This is the machine that embosses the state code and number on the screen printed blanks. The blanks are fed in pairs by the one person at the back and the operator set the dies that will emboss the state code and number at the front of the machine. The embossed blanks dropped at the conveyor sides where they were collected.

3.4 Coating

Coating Section - The embossed plates are kept on the coating machine where they are coated red, blue, green or black as the case may be. After the plates are coated, they are passed to packaging and inspection section where they are being checked for defects before the plates are packaged and transferred to the store for dispatch to respective states that have placed order for the plates.

4. DEVELOPMENT OF MATHEMATICAL MODEL

The basic stages in Vehicle Number plate production were studied and from the data obtained at production floor showed that the plant rely heavily on standby generator throughout the production processes, experienced hands are engaged in the processes and there is a defined responsibility for each production worker while all activities are subject to monitoring and evaluation. The machines are readily available except during minor repairs/ slight breakdown.

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

$$t = \sum_{i=1}^{n} t_i \qquad \textbf{(1)}$$

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

The $variable_i$ represents the various workstations of interests (blanking, screen printing, embossing, coating etc).

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

$$\frac{d_{m_i}}{dt} = \Delta_{m_i},$$

where $\Delta = \frac{d}{dt}$

Also, if (w_i) represents the human worker at $workstation_i$ and the workers work for a period of time t units, then we can express the rate of working of this worker as

$$\frac{d_{w_i}}{dt} = \Delta_{w_i},$$

where $\Delta = \frac{d}{dt}$

Since in time study activities a provision of allowance is always necessary, a parameter '$\boldsymbol{T_a}$' into the model. Therefore, the general mathematical expression for the production time t_i at each workstation is given as;

$$\boldsymbol{T_i} = \frac{\Delta}{m_i} \times \frac{\Delta}{w_i} \times f(y_i) + \boldsymbol{T_a} \qquad \textbf{(2)}$$

Where $f(y_i)$ is a normalizing function which converts the expression into time units

Substituting Equation 2 into 1 gives the following equation.

$$t = \sum_i^n \left(\frac{1}{\Delta m_i} \times \frac{1}{\Delta w_i} \times f(y_i) + \boldsymbol{t_a}\right) \qquad \textbf{(3)}$$

$$t = \sum_i^n \left(\frac{1}{\Delta m_i} \times \frac{1}{\Delta w_i} \times f(y_i)\right) + \sum_i^n \boldsymbol{t_a} \qquad \textbf{(4)}$$

but $\sum_i^n \boldsymbol{t_a} = n\boldsymbol{t_a}$

$$\therefore \quad t = \sum_i^n \left(\frac{1}{\Delta m_i} \times \frac{1}{\Delta w_i} \times f(y_i)\right) + n\boldsymbol{t_a} \qquad \textbf{(5)}$$

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

$$t = \left(\frac{1}{\Delta m_i} \times \frac{1}{\Delta w_i}\right) \sum_i^n f(y_i) + n\boldsymbol{t_a}$$

The model is generalised by taking $f(y_i)$ as $f(y)$:

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$\frac{1}{\Delta m_i}$ *as* $\frac{1}{\Delta m}$ *and* $\frac{1}{\Delta w_i}$ as $\frac{1}{\Delta w}$

Thus $t = \frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(y)\,dy + nt_a$

(6)

Assuming that the total number of units produced is denoted by symbol (x), while T is the total time spent for all the units, Equation (6) above becomes,

$T = xt = x\left(\frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(y)\,dy + nt_a\right)$

(7)

Raw materials and electricity supply

In the application of the mathematical model, some factors could militate against reaching the production targets. Factors highly considered are electricity supply fluctuation and unavailability of raw materials which are functions of these parameters; $f(y_i)$ and $f(y, z)$. Therefore, Equation (7) is expressed as follows:

$T = xt = x\left(\frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(y,z)\,dydz + nt_a\right)$

(8)

5. APPLICATION OF THE MODEL AND DISCUSSION

The plant operates an eight hour daily production cycle which commences from 8am and ends at 4pm. However, daily working hours of workers may increase where there is higher demand of Number plates. The production floor of the plant has a minimum of 16 workers who manned various machines on the floor.

The general formula for the total time spent in producing (x) units is given in the equation below (Oke, 2006)

$T = xt = x\left(\frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(y)\,dy + nt_a\right)$

Where T is the total time spent for all the units,

x is number of units produced,

n is number of workstations and t_a is the time allowance.

Assuming that the electricity supply index (y) obeys a linear function such as 2y+5, then the expression becomes f(y) = 2y+5. From the actual observation, the mathematical model that fit the time problem in terms of number of machines is:

$t = my^3 + m^2y^2 + y$

(9)

Differentiating Equation (9) gives:

$\frac{dt}{dm} = y^3 + 2my^2$

(10)

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

$t = wy^3 + w^2y^2 + y$

(11)

Differentiating above gives:

$\frac{dt}{dw} = y^3 + 2wy^2$

(12)

Note that (n) has been stated earlier to be the number of workstations, and (t_a), the time allowance. If 2000 units are produced in the plant for 30 seconds per unit, then t_a = 2000 × 30 seconds. Therefore, t_a = 60000 seconds.

Taking the production process into the analysis, there are five workstations for the Number plate production processes, hence n = 5. Recall Equation (6)

$t = \frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(y)\,dy + nt_a$

But $\frac{1}{\Delta m} = y^3 + 2my^2$ and $\frac{1}{\Delta w} = y^3 + 2wy^2$

The average period electricity fails in a day is 65 minutes, while the average daily working time is 8 hours.

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

$y = \frac{65 \text{ minutes}}{8 \times 60 \text{ minutes}} = \frac{65}{480} = 0.1354$

This gives an index value of 0.1354

Note that the number of machines m = 5, number of workers, w = 16. Since f(y) = 2y+5, the Equation (6) is evaluated by substituting the function as follows:

$t = \frac{1}{\Delta m} \times \frac{1}{\Delta w} \int_1^n f(2y+5)\,dy + nt_a$

so $t = \frac{1}{\Delta m} \times \frac{1}{\Delta w} (y^2 + 5y + c) + nt_a$

Note that at the start of production process, all the factors are zero. This gives the production constant c to be zero.

$\therefore t = \frac{1}{\Delta m} \times \frac{1}{\Delta w} (y^2 + 5y) + nt_a$

Inputting the necessary values into the equation gives:

$t = (y^3 + 2my^2)(y^3 + 2wy^2)(y^2 + 5y) + nt_a$

$((0.1354)^3 + 2(5)(0.1354)^2)$ $((0.1354)^3 + 2(16)(0.1354)^2)$ $((0.1354)^2 + 5(0.1354)) + 5(60000)$

= (0.1858) (0.5891) (0.6953) +300000

= 300000.076 seconds

$t = \frac{300000.076}{3600} = 83.33$ hours

Note that t_i = 30 seconds per unit,

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Therefore the total units produced in 300000.076 seconds

$= \frac{300000.076}{30} = 10000$ units

That is 10000 units of Number plate would be produced in 83.33hrs

6. CONCLUSION

The production of Number plate has been thoroughly examined and the five basic operational activities were carefully studied. The study revealed that the setting of standards for achieving production targets for the plant is very imperative in eliminating time gap which would permit parallel production of the Number plates.

One of the techniques for achieving this aim is the application of a mathematically developed time-based model in monitoring and control of workers at the production floor. In this paper, the time study concept in a production process is modelled mathematically using differential calculus to the elements of the production system that have significant effect on the output production from the system. The study is however considered very crucial in this period when the Corps is in the drive to sanitize the motor vehicle administration.

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