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Development of Model for Determination of Crew-Size Requirements for a Bolt and Nut Manufacturing Industry

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Abstract: Effective and efficient running of bolt and nut manufacturing industry demands determination of it's optimal crew-size requirement. In this study, a model was developed to determine the number of manpower required (Q) in terms ofannual production target (μ); production efficiency (P) machine efficiency (P o) and operators efficiency (P m); expected number of required man-hours (N) and the total production time (T). Data were collected from Oyeladun Manufacturing Industry, Ogbomoso Oyo State on types and number of machine tools available; working hours per day; number of working days per week. The model parameters were estimated as follows μ (52,240), P (85%) and N (0.1877). The optimal number of personnel required by the organization was estimated to be six.

Key words: Man-hours, efficiency, production time, crew size, bolt and nut

INTRODUCTION

In past years, it has been discovered that the collapsing of manufacturing industry is due to the inability to identify and make efficient use of human resources. As a result firms have increasingly recognize the potential for their people to be a source of competitive advantage in order to achieve its goals and match its set standard (Pfeffer, 1994). Thus human resources determination like any form of planning is a means to achieve the corporate objective of a manufacturing industry. Many researchers has demonstrated statistical significant relationship between human resources determination and firm profitability (Delary and Doty, 1996; Guthrie, 2001; Huselid, 1995).

While these studies have been useful for demonstrating the potential value created through human resource, they have revealed very little regarding the processes through which this value is created (Wright and Garnder, 2002). Some authors have referred to this as the black box, problem noting that the conceptual development of the mediating mechanism through which human resource management has an impact on profitability has thus far eluded empirical testing (Purcell *et al.*, 2003).

In addition, the vast majority of studies examining the relationship between human resource practices and firm performance have been entirely cross sectional in their design, although it produced useful information, the design is problematic. Delary and Doty (1996) examined the relationship between human resources practices and profitability in a simple of banks in the United State and found that they were positively related, Guthrie (2001) reported that the true resource determination between retention and productivity was posi8tive when manufacturing industry implemented high involvement human resources determination practice, but negative when they did not MacDuffie (1995) found, that the human resources determination practices in manufacturing industry 'bundles' he measured were related to quality and productivity while (Youndth *et al.*, 1996) discovered that human enhancement of human resources determination were related to operational performance.

Dyer and Reeves (1995) reviewed much of the existing research in the relationship between human resource practice and performance and proposed that measures of performance could be broken down into four categories. First, employee outcome deal with the behavior, particularly behavior such as absenteeism and turn over. Organizational outcomes focus on more operational measures of performance such as productivity, quality and shrinkage, many or all of which would be precursors to profitability.

In this study, attempts was made to develop a model to determine the optimal crew size for a bolt and nut manufacturing industry with view of optimizing the operational time and enhancing profitability.

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MODEL DEVELOPMENT

Andrew and Mclone (1978) found that the number of man hours is directly proportional to the production time and inversely proportional to the production efficiency with constant of proportionality being the expected production output.
Expressing mathematically,

$$N = \mu \frac{T}{P} \tag{1}$$

Where
N = Number of man-hours required for production output
μ = Production target
T = Production time
P = Production efficiency

In this case production time is the sum total of machining operation time for each bolt d nut.
That is

$$T = T_N + T_B \tag{2}$$

Where
T_B = Total machining operation time for bolt.
T_N = Total machining operation time for nut.

Seven identified machining operations and their corresponding standard formulae for estimating machining time for each of bolt and nut are presented in Table 1.

Combinining these standard formulae, the total machining time for nut may be estimated as

$$T_N = \frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{pitchN_d} + \frac{L}{N_D S_r} + \frac{L}{S_i n_g} \tag{3}$$

Also, machining time for Bolt

$$T_B = \frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{S_i n_g} + \frac{L}{PitchN_d} \tag{4}$$

Combine Eq. 3 and 4

$$T = TN + TB = \left(\frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{pitchN_d} + \frac{L}{N_D S_r} + \frac{L}{S_i n_g} + \left(\frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{S_i n_g} + \frac{L}{PitchN_d}\right) \tag{5}$$

Also, Adejuyigbe (2002) stated that production efficiency is the product of machine efficiency and operator efficiency.
That is

$$P = P_m \times P_{o=} \tag{6}$$
$$P_m = \pi_P$$

Table 1: Machining operations for manufacturing bolt and nut

Machining operation	Machining time for nut (T)	Machining time for bolt (T)
Metal cutting	$\frac{L_C}{S_i n_c}$	$\frac{L_C}{S_i n_c}$
Milling	$\frac{L}{Z_E Z N_m}$	$\frac{L}{Z_E Z N_{im}}$
Turning	$\frac{L}{Feed/rev(s) N_T}$	$\frac{L}{Feed/rev(s) N_T}$
Threading	$\frac{L}{PitchN_d}$	$\frac{L}{PitchN_d}$
Drilling	$\frac{L}{N_D S_\gamma}$	
Grinding	$\frac{L}{S_i n_g}$	
Necking		$\frac{L}{S_i N_n}$

Source: Adebiyi and Mudashiru (2006). Metal Cutting, L = length of longitudinal travel, I = Number of passes, S_i = Longitudinal feed in mm. Milling, L= Traveling distance of milling table, Z_E = Number of teeth in cutter, N_m = Cutting speed in rpm. Turning, L= Length to be turned, N_T = Turning speed, Threading, L= Length to be thread, N_d = Speed of threading. Drilling, L= Length of travel of drill, S_r = Feed per minute, N_D =Speed in rev/min

But

$$P_m = \prod_{m=1}^{R} P_{km} \tag{7}$$

and

$$Po = \prod_{1=i}^{k} P_{km} \prod_{m=1}^{R} P_{km} \tag{8}$$

P_m => machine efficiency for each operation
Substitute 7 in 6

$$P = \prod_{1=i}^{k} P_{km} \prod_{m=1}^{R} P_{km} * \prod_{m=1}^{R} P_{km} \tag{9}$$

Where P_{km} is efficiency of operator k on machine m and P_m is efficiency of the machine m.

Combining Eq. 5 and 9, the total man-hours required for production of bolt and nut may be estimated by

$$N = \left[\left(\frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{pitchN_d} + \frac{L}{N_D S_r} + \frac{L}{S_i n_g} + \frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{S_i n_g} + \frac{L}{PitchN_d}\right) \left(\prod_{1=i}^{k} P_{km} + \prod_{m=1}^{R} P_{km} *. \prod_{m=1}^{R} P_{km}\right)\right] \tag{10}$$

According to Charles-Owaba (2002) the number of manpower required for a production organization may be define as the ratio of total production man-hours to annual available man-hours.

$$Q = \frac{N}{H} \quad (11)$$

The annual available man-hours is given as

$$H = D^* \, Y \quad (12)$$

Where, D is daily operational hours and Y is days of operation in a year substituting Eq. 10 and 12 in 11, the crew size for a bolt and nut manufacturing company may be given as

$$Q = \frac{1}{D \times Y}[(\frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{pitchN_d} + \frac{L}{N_D S_r} + \frac{L}{S_i n_g} + \frac{L_i}{S_i n_c} + \frac{L}{Z_E Z N_m} + \frac{L}{FeedN_T} + \frac{L}{S_i n_g} + \frac{L}{PitchN_d}) * (\prod_{k=1}^{k} Pkm * \prod_{m=1}^{R} Pkm \,.\, \prod_{m=1}^{R} Pkm) \quad (13)$$

MODEL APPLICATION

A bolt and nut manufacturing company located in Ogbomoso was used for the application. Data were collected to estimate the model parameters. The estimation of parameter values is shown in Table 2 and 3.

Overall operation time for bolt and nut, T = 5.23 + 6.03 = 11.26 min. Converting to hours

$$T = \frac{11.26}{60} = 0.1877h$$

According to Adejuyigbe (2002) the overall production efficiency is determine to be 85%

Therefore, P= 85% = 0.85

Production target, μ= 54,240

Employing Eq. 1

Table 2: Operational conditions of a bolt and nut manufacturing industry

Manufacturing industry	Number of working hours/ day	Number of working days per week	Annual production target	L	D	M	a	S
Oyeladun	9	5	54,240	1	1	2	3	1

L: Lathe machine. D: Drilling machine. M: Milling machine. a: Grinding machine. S:Shaping machine

Table 3: Operations/operation times for bolt and nut

Operations/operation time	Bolt	Nut
Metal cutting	1.40	1.40
Milling	0.13	0.13
Turning	2.20	2.20
Threading	1.20	1.20
Necking	0.30	-
Drilling	-	0.80
Grinding	-	0.30
Total time	5.23	6.03

∴ The number of man-hours,

$$N = (54,240)\frac{0.1877}{0.85} = 11,977.467 \approx 11978$$

Also, from Eq. 11 annual available operation hours can be determined thus,

H = (9×5)(4×12) =2160

Using Eq. 10 the number of manpower required is

$$Q = \frac{11978}{2160} = 5.54$$

Thus, Q≈6.

RESULTS AND DISCUSSION

A linear model was developed for the determination of an optimal manpower required for a bolt and nut manufacturing industry taking into consideration the annual production target, the production efficiency and the total production time. The production efficiency is determined from the combination of machine and operator efficiencies. Also, the total production time is the sum total of all the machining times. The machining operations involved include metal cutting, turning, drilling, milling, threading and necking.

A nut and bolt manufacturing company based in Ogbomoso, Oyeladun Manufacturing Industry, was used to validate the model. The data collected from the organization was used to determine the model parameters. The annual production target was found to be 52, 240 units of bolts and nuts. Based on Stephenson (1996) and Adejuyigbe (2002) the production efficiency was calculated to be 85%.

Thus both the machine hours and man-hours are available for a very good time with less downtime. Moreover, the actual production time for all the machining operations was estimated as 0.1877 h. Therefore, the actual number of man hours required was estimated as 11978 operating hours per week. These were used to estimate the optimal number of personnel required for the establishment as six.

This implies that optimal crew size of six personnel will be cost effective for this establishment. This suggests that a lesser number being employed may lead to increase in the working hours per day or number of working days per week to be able to meet with the production target and these can be at long run affects the efficiency of both the machine and the operators, as less hour will be available for rest in both cases.

However, if higher numbers of workers are employed, this will create additional cost for the organization and reduction in efficiency of operators as a result of redundancy.

CONCLUSION

The model developed for a bolt and nut manufacturing industry is formulated considering the previously determined parameter in conjunction with other assumption to determine the required human resources. The model was developed as an aid to manufacturing industry planning to help human resources manager and planning staff to make set of assumption about future demand for labour and to see the likely effect on profit, return on capital etc.

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