Cost Minimization Approach to Manpower Planning in a Manufacturing Company.

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ABSTRACT

This study proposed a method for the determination of the optimal number of workers required in the factory of a manufacturing company. The method is a combination of a simple queue model and regression analysis. The data necessary for the method include the sales per day, units produced per day, number of workers at work per day, labor costs, as well as the realizable profit on each of unit of products. With this method, it was established that the company needs 6 additional workers on the production line to achieve a production of 22,750 units per annum.

(Keywords: manpower planning, queue model, regression analysis, manufacturing company)

INTRODUCTION

One of the goals of any organization or business enterprise is to satisfy a particular demand, and in doing so, the organization must have sufficient capacity. The capacity of any organization consists of machines, money, materials, and manpower (human resource). Human resources are valuable to all organizations, not only because of their ability to render services even in highly automated industries, but also because they are costly to acquire and develop and that substantial investments are required in order to build an effectively functioning human organization. As noted by Skulj et al. (2008), a crucial task of managing a large organizations such as industrial companies, state administration, military systems, and transportation is efficient manpower planning.

Meyer (1967) emphasized the importance of human assets and their utilization as he opined that the success in the business world in the coming decade is to be determined by the efficient utilization of human resources. He asserted that companies that will prosper in the future will be those that do the best job in fully utilizing their human resources. According to Walker (1972), a company ought to have a clear idea of her manpower needs and what they are likely to be in the future.

Moreover, Dill et al. (1966) pointed out that the basic considerations involved in manpower planning include specification of the kinds and numbers of men the organization may need to accomplish its profit, growth, or service objectives. The determination of the exact number of workers for products with short lead time and increased shorted product life cycle put pressure on the decision makers.

A common strategy used by managers to sustain a competitive advantage is to introduce new products. This creates pressure on manufacturing to respond quickly to changes in demand characteristics. The challenge for managers is to determine how many additional workers to employ to satisfy a varying market (Kurawarwala and Matsuo 1996). A right-size of workers would minimize cost associated with not satisfying the market and maximize the profitability of the organization.

Both Gascoigne (1968) and Drui (1963) observed that regression analysis may be a useful tool in manpower planning. Oke (1992) thus made use of regression analysis. Similarly, Goh and Teo (2000) used time series projection to forecast manpower by examining a relationship solely between the past behavior and time and then extrapolate the trend into the future. In fact, Wang (2005) and Wong et al. (2008) gave a good review of manpower planning models.

Also, Aston and Gillson (1980) successfully applied queuing models to determining the optimal number of a maintenance force in a company producing drop forging. Taha (1972) also employed queuing models to determining the number of typists in a pool. While complex models can supply very accurate results, they often require data that are not easy to collect or parameters that may only be vaguely known especially if a very large number of them have to be specified. Consequently, the reliability of the resulting outputs is then put to question for very large systems.

Simpler and more robust models are often a better choice (Skolj et al., 2008). A model that may combine both queuing model and regression analysis may be a better model for determining the optimal number of workers and in addition link the manpower requirements to the output in the industry. Williems (1998) proposed a forecasting model which linked the manpower requirements to the output of the industry and to the developments in the rest of the economy. This study attempts to propose a method to determine an optimal number of workers in a manufacturing organization.

METHODOLOGY

Data from the company (a refrigerator company in Ibadan, Nigeria) were collected with the aid of questionnaires and personal interviews. The data collected included:

(i) Number of units sold per day
(ii) Number of units produced per day
(iii) Number of workers on duty per day
(iv) Wages and allowances paid to the factory workers for the period under review
(v) Profit accruable on a unit of product sold.

The data on sales and units produced were tested as to whether they follow a poisson distribution. A curve fitting of the number of workers and number of units produced was done and the model with highest correlation coefficient was determined.

A simple Queuing model of the form M/M/1: FCFS/∞/∞ was assumed for the production company due to the following:

(1) Sales (arrivals) rate and production (service) rate normally occur randomly. Though sales and production targets are normally set, actual quantities cannot be known with certainty.

(2) A production line regarded as a single server since a product is not complete until it is ready for sale.

(3) A "First Come First Served" discipline is obeyed by products of same type.

(4) Since there is no limitation imposed on the number of products to be sold, except the installed capacity of the machines of the company, there may be no limit to the number of units to be produced provided there is demand for the product.

(5) A steady state exists in the company since the number of products sold cannot be more than the units produced.

The above simple queuing model denotes poisson arrival (exponential inter arrival), poisson departure (exponential service rate), single server, first come first served discipline, an infinite number in the system, and infinite calling source. Thus, the number of units (products) awaiting production and those under production was determined using the relation (Taha 1972):

$$N_P = \frac{\rho}{1-\rho} \qquad \textbf{(1)}$$

where $\rho = \frac{\lambda}{\mu}$ = Traffic Intensity

λ = Mean Arrival Rate (units sold/day)

μ = Mean Departure Rate (units produced/day)

RESULTS AND DISCUSSIONS

From the data presented in Table 1, the production rate, μ_p = 4.5 units per hour. Similarly, the sales rate, λ_s = 4.39 units per hour. At the 95% level of significance, the production rate followed poisson distribution as the chi-square for 10 degrees of freedom (12.924 does not exceed the critical value of 18.307).

Similarly, the sales rate followed poisson distribution as the chi-square for 7 degree of freedom (11.804 does not exceed the critical value of 14.067).

Table 1: Compressed Data on Sales and Units Produced.

Number of Units	Frequency for Units Produced/hour	Frequency for Sales/hour
0	2	4
1	11	8
2	8	10
3	24	15
4	21	22
5	18	13
6	18	15
7	5	0
8	6	2
9	5	3
10	1	2
11	0	2
12	1	1
13	0	0
14	1	0
15	0	0
16	0	0
17	0	1

Labor Costs: There were 88 workers in the factory distributed as follows:

1. Machine Section: This section had 11 workers involved in notching, blanking, shearing, and punching of metal sheets based on the drawings of the part in question.

2. Welding Section: The section with 10 workers undertook all the welding jobs using spot, arc, and oxy-acetylene welding techniques in respect of the inner and outer cabinets of the refrigerator.

3. Washing Section: The welded and pre-assembled cabinets were sent to the pre-treatment plant for washing and oven drying to remove dirt or oil and prepare the surface for painting. The section had 4 workers and complained of inadequate manpower. This was evident as there were some cabinets on queue in this section.

4. Spraying: The washed and pre-assembled cabinets were sent into the painting section for powder coating. The section had 5 sprayers.

5. Foaming Section: This section was concerned with preparing the cabinets for foaming and injecting foam chemicals into the cabinet and allowed to cure for between 5 and 7 minutes. There were 6 workers in this section and some cabinets to be prepared were on queue due to inadequate manpower.

6. Screen Printing: The section is concerned with branding the refrigerator. There were only 4 workers in this section.

7. Final Assembly: Good screened cabinets were sent to the final assembly section where already prepared cooling system, evaporator cover, fluorescent fittings and tube, plastic logo of the company, suction line cover, stabilizer unit, glass door, front grid, harness plate, overload and relay were all fitted. The section had 12 workers.

8. Unit (Cooling Preparation): Unit section had 10 workers concerned with cutting of copper pipe, testing for leakage using nitrogen, and brazing of the copper pipe to compressor, evaporator and condenser. They were also saddled with the responsibility of vacuuming, charging (refrigerant gas).

9. Electrical Harness: The section with 10 workers was in charge of cutting required lengths of various sizes of electrical cables, fixing thermostat, fan motor and so on.

10. Door Assembly: In this section, aluminum profiles were cut into lengths and holes at required distances drilled on them. They also fitted magnetic gasket, sheet glass and door handle. The section had 4 workers.

11. Quality Control Section: The section with 4 workers certified the products for onward transfer to the warehouse/customers after necessary tests had been carried out on them.

12. Packing Section: This was where certified refrigerators were properly cleaned and fitted with label, shelves, and drip tray. The products were then packaged into cartons and tied with polyflex straps. The section had 8 workers.

The labor costs obtained from the company is shown in Table 2. During the year under review (year 2007), the factory had 88 workers in the factory and this amounted to a worker being paid N 1056.02 per worker per day for 250 working days.

Table 2: Labor Costs for Year 2007

Item	Amount per annum (N)
Wages	18,432,440
Utility 2 Allowance	1,600,000
Lunch Allowance	3,200,000
TOTAL	**23,232,440**

Relationship between Number of Workers and Number of Units Produced: In order to establish the relationship that exists between the number of workers in the company and the number of units produced by them, a regression analysis was done using SPSS 16.0. The result of the analysis is presented in Table 3.

From Table 3, it is evident that the cubic equation with the highest value of R^2 (0.605) best represents the relationship between the number of workers and the number of units they produced.
Thus, Number of Units Produced,

$$Y = 417.666 - 0.225X^2 + 0.002X^3 \quad \textbf{(2)}$$

In column 2 of Table 4, the number of units produced was determined using Equation (2) while the number of units of the products awaiting production due to insufficient manpower (column 3) was determined using Equation (1).

The associated labor cost is shown in column 4 while the profit that may accrue to the company if the specified number of products are produced, which in this case is lost due to the number of products awaiting production, is shown in column 5. Column 5 was calculated by multiplying the profit accruable from the sale of a unit of the product (N 9,220.20) with number of units awaiting production (column 3).

The last column represents the total cost is the sum of columns 4 and 5. The optimal cost is the minimum value in column 6.

The minimum cost possible, as highlighted in Table 4, is N 105,056.01 and the number of workers corresponding to this value is 94 with a production rate of about 91 units per day.

The company presently has 88 workers with a total cost of N 193,461.54. By engaging additional 6 workers that should be distributed between washing and foaming sections to reduce the number of works in progress at this sections, the company could produce about 91 units per day. The amount translates to 22,750 units per year (a year of 250 working days). The annual quantity expected from the company by her foreign partners was 22,000 units.

Table 3: Model Summary and Parameter Estimates.

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.587	96.592	1	68	.000	-347.864	4.607		
Logarithmic	.583	95.259	1	68	.000	-1.642E3	379.537		
Inverse	.580	93.886	1	68	.000	411.290	-3.123E4		
Quadratic	.603	50.871	2	67	.000	1.458E3	-39.130	.264	
Cubic	.605	51.246	2	67	.000	417.666	.000	-.225	.002
Compound	.480	62.665	1	68	.000	6.311E-5	1.170		
Power	.486	64.278	1	68	.000	2.693E-24	13.041		
S	.492	65.924	1	68	.000	16.413	-1.083E3		
Growth	.480	62.665	1	68	.000	-9.671	.157		
Exponential	.480	62.665	1	68	.000	6.311E-5	.157		
Logistic	.480	62.665	1	68	.000	1.585E4	.855		

Dependent Variable: Number of Units Produced, Y
Independent variable is Number of Workers, X.

Table 4: Number Of Workers In The Factory And Associated Cost.

NUMBER OF WORKERS, X	NUMBER OF UNITS PRODUCED, Y	NUMBER OF UNITS AWAITING PRODUCTION	LABOR COST	LOST PROFIT	TOTAL COST
88	38.21	10.90342679	92,929.76	100531.7757	193,461.54
89	45.379	3.372193853	93,985.78	31092.30176	125,078.08
90	53.166	1.926676208	95,041.80	17764.33998	112,806.14
91	61.583	1.31663093	96,097.82	12139.6005	108,237.42
92	70.642	0.981987543	97,153.84	9054.121542	106,207.96
93	80.355	0.771690001	98,209.86	7115.136148	105,325.00
94	90.734	0.627982919	99,265.88	5790.128109	105,056.01
95	101.791	0.524022698	100,321.90	4831.594077	105,153.49
96	113.538	0.445644147	101,377.92	4108.928162	105,486.85
97	125.987	0.384670338	102,433.94	3546.737446	105,980.68
98	139.15	0.336053769	103,489.96	3098.482957	106,588.44
99	153.039	0.29651217	104,545.98	2733.901507	107,279.88
100	167.666	0.263820421	105,602.00	2432.477048	108,034.48
101	183.043	0.236417798	106,658.02	2179.819377	108,837.84
102	199.182	0.213178058	107,714.04	1965.544335	109,679.58
103	216.095	0.193268726	108,770.06	1781.976311	110,552.04
104	233.794	0.176061652	109,826.08	1623.323642	111,449.40
105	252.291	0.16107432	110,882.10	1485.137442	112,367.24
106	271.598	0.147930245	111,938.12	1363.946441	113,302.07

CONCLUSION

A combination of a queue model and regression analysis was used to determine the optimal number of workers in a factory. The factory used as a case study was a refrigerator company where an optimal number of workers on the production line was determined to be 94 as against the present number of 88 workers. Though the method gives an indication of the number of workers in need presently, the table so derived may be a guide for the management in the determination of the number of workers needed to produce a certain number of units.

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