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A Dynamic Model for Sequential Expansion in Building, Machinery and Manpower Based on Gradual Funding

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Abstract

Adequate resources such as land, manpower, and material that are supportive to industry construction and development are available in many developing countries such as Nigeria. Development of these resources to the industrial level is, in most cases, being hindered by inadequate funding which is critical in the effective transformation of the industry to the set target. The funding, no matter how meagre it is can still be used effectively if a framework that allows sequential disbursement of it is in place. This study provides a dynamic model that is capable of sequentially expanding the industry building, outputs, machinery and manpower based on the level of funding, while the targeted capacity are not violated. In the model the quantity produced (output) is controlled by the size of machinery and manpower which in turn determines the size of the building. The three parameters of control; namely industry's output, machinery and manpower are modeled using multiple regression method. Funding serves as prime mover on the road of meeting the expected target. The system also allows the prediction of expected capacity so that arrangement is made for meeting the future industry's building size requirements. The implementation of the model in a wire and cable industry in Nigeria shows that the expansion of the industry's building varies with types of products, size of output, machinery and manpower, the available fund can cope with. This makes the model to have potential in solving the problem posed by funding on the development of industry in developing economy.

Keywords

Sequential expansion, Control system, Industry construction, Funding, Demand target

1. Introduction

Adequate resources such as land, manpower, and material that are supportive to industry construction and development are available in many developing countries such as Nigeria. Development of these resources to the industrial level is, in most cases, being hindered by inadequate funding which is critical in the effective transformation of the industry to the set target (Oyekan, 2000; Koyoshi, 1987). The funding, no matter how meagre it is can still be used effectively if a framework that allows sequential disbursement of it is in place (Sunchrum, 1990). A good industry construction is required to be flexible, robust and easily lend itself to expansion and/or contraction in the process of meeting the needs of the customers (Teriba *et al.*, 1981; Richard, 1982, 1986). The change in population could certainly influence the demand of commodities in the industry. Without an iota of doubt, an agile industry will always attract more customers than its counterparts that are weak (Richard, 1988). However, if the industry is not agile and there is increase in population of customers, some customers may still be forced to patronize it if it maintains a certain level of operational sanity. Therefore, the industries generally should find ways of predicting the magnitude of their customers for proper planning in satisfying them through launch of appropriate facilities expansion or contraction strategy. In developing countries such as Nigeria, due to low capital outlay, the demands may not be satisfied at once, instead it could be satisfied gradually with concurrent and sequential expansion of industrial facilities such as building, machinery/raw material and manpower based on available funds. This gradual developmental effort will also reduce wastes from industrial processes including overproduction, inventory and defects, as all outputs will be consumed by the customers. This study provides a dynamic model that is capable of sequentially expanding the industry building, outputs, machinery and manpower based on the level of funding, while the targeted capacity are not violated. The study is different from similar others in literature including Aderoba (1997) and Idris, and Aderoba (2001) with the inclusion of manpower, raw material and demand constraints from which the past efforts are deficient. This study assumed that additional machinery, raw material, manpower, and space procured are similar in performance to the existing ones.

2. Model Formulation

Sequential transformation of machinery and manpower, with the attendant change in factory building space for improving production output performance in the industry are illustrated in Figure 1 as a close loop control system with target demand as input and the quantity produced as output.

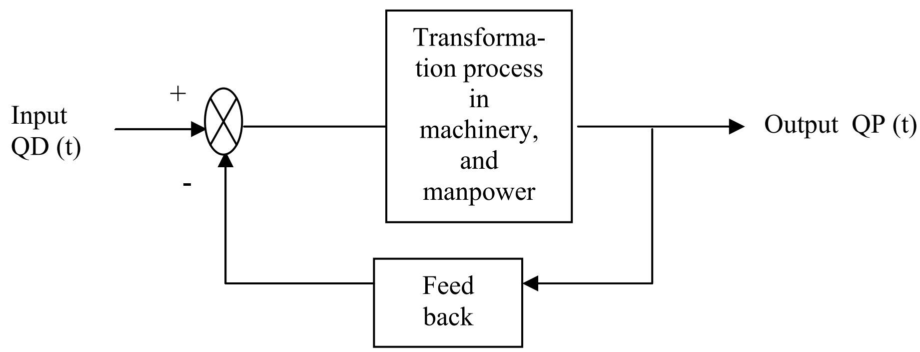

Figure 1: Control System for Machinery and Manpower

Let QP (t) be the quantity produced at time (t), and QD (t) the quantity demanded at time (t), then production output shortfall (error) at time t, E (t) from Figure 1 is estimated from

$$E(t) = QD(t) - QP(t) \quad (1)$$

If $E(t) \leq 0$, demand has been met, there is no need for more funding. Then if $E(t) > 0$, demand target has not been met, therefore further funding is required, to obtained more production facilities either concurrently or sequentially, for increased output QP(t). The funding may be obtained through plough back of profits, directors' contribution and loans from financial institutions. However, loans from many financial institutions in developing countries such as Nigeria are being saddled with high interest rate; therefore the contributions based on plough back of profit and from directors could be planned for, kept in bank periodically, cumulatively added over these periods with the inclusion of time value of money based on interest and inflation. The money is augmented over the periods until it is enough to purchase a unit of machinery, raw material, and factory space in one sequence and to employ a unit of manpower (including working space) to operate the machinery in the other. The operation of this additional system will definitely contribute some percentages increase in the production outputs. The amount of output contributed is dependent on trend obtained from the previous production outputs from the facilities on ground which mainly comprise machinery and manpower; and can be dealt with separately or jointly because they may have different contributions to the output from which the value added to the output can be determined (Folayan *et al.*, 1986). Under the assumption of linear regression trend (Havper, 1991), the contributions to periodic outputs, QP(t) for machinery (m) and manpower (w) are separately given by Equations 2 and 3, and are jointly expressed in Equation 4.

$$QP_m(t) = a + bMac\_x_2 \quad (2)$$

$$QP_w(t) = a' + b'Man\_x_3 \quad (3)$$

$$QP(t) = a'' + b''Mac\_x_2 + b'''Man\_x_3 \quad (4)$$

Where, QP(t) is the projected trend production output at time t, Mac_x_2 is economic indicator for machinery used for production (in term of output contribution), Man_x_3 is the economic output contribution from manpower; a, a', a'', b', b'' and b''' are the coefficients of the regression Equations.

The production outputs from Equations 2, 3 and 4 are substituted separately into Equation 1, from which errors from the target demands are determined. First, machinery with its components namely building space and raw material are to be procured concurrently because of their close relationship. Second, manpower included working space is then employed for the operation of the machinery, too. Let the total cost of obtaining additional machine (with factory space) be X_c, and periodical plough back be λ; the decision rule is, if the money available (profit) cannot purchase the machinery, it is deposited in bank or invest in another profitable venture. This made the next plough back be adjusted base on accrued interest and inflation (Akanbi *et al.*, 2001). Therefore, the future funding λ^{tn} can be obtained as

$$\lambda^{tn} = \lambda^{to}(1+j)^n \quad (5)$$

Where, j is interest rate and n is counter for periods (n=1, 2, 3, ...). Equation 5 is useful if there is no change in the value of plough back (reinvested amount) over the period. If there is a change in plough back value with further inflation, k influence at subsequent periods, then,

$$\lambda_m^{tn} = \lambda^{to} [(1+j)^{n-1} (1+j) + \sum_{t=0}^{n-1} (1+k)^{n-1}] \quad (6)$$

Where, k is the inflation factor. The optimal policy is to find the number of periods, n in which $\lambda^{tn} = \lambda_m^{tn} \geq X_c$. At this period, a machine is procured. Then the leftover $\theta \geq 0$ is $\lambda_m^{tn} - X_c$. Introducing θ, into Equation 6, then the fund for procuring the required raw material (including factory space) of cost, Y_c for the machine is obtained from Equation 7,

$$\lambda_y^{tn} = [1+j]^{n-1} [(\theta + \lambda)^{to} + \lambda^{to} \sum_{t=0}^{n-1} (1+k)^{n-1}] \quad (7)$$

In Equation 7, optimal policy is to obtain the period when the raw material is to be purchased. Similarly funding for manpower (including work space) that costs Z_c with the leftover, $\Psi = \lambda_y^{tn} - Y_c$ and $\Psi \geq 0$

$$\lambda_w^{tn} = [1+j]^{n-1} [(\Psi + \lambda)^{to} (1 + j) + \lambda^{to} \sum_{t=0}^{n-1} (1+k)^{n-1}] \quad (8)$$

The optimal period is when $\lambda_w^{tn} \geq Z_c$; at this level both machinery and manpower would have been separately increased by a unit. The most important inference that can be drawn at this stage is the determination of the magnitude of contribution of each additional facility to overall production output. Let q and s be the contributory factors for machinery and manpower, respectively, then, the cumulative outputs are obtained from the Equations 9 and 10. Their values are substituted into Equations 2, 3 and 4 for the computations of total outputs. The outputs from Equations 2 and 3 are measures of degree of contribution (value added) to the overall output of each of facilities in question. The resulting output from Equation 4 is then compared with the demand target in Equation 1.

$$Mac\_x_2 = Mac\_ x_2 (1+q) \quad (9)$$

$Man\_x_3 = Man\_ x_3 (1+s)$ (10)

If the first iteration has not given the optimal results for the elements considered. Then, fund is augmented for the first priority element – industrial machinery in this case. With the leftover Φ from the manpower procurement i.e. $\Phi = \lambda_w^{tn} - Z_c$. Where, Z_c is the cost of procuring manpower to utilize the purchased machinery. Fund augmentation for the purchase of another machinery is obtained base on leftover from previous procurements and is given as

$$\lambda_{m2}^{tn} = [1+j]^{n-1} [\Phi + \lambda)^{to} (1 + j) + \lambda^{to} \sum_{t=0}^{n-1} (1+k)^{n-1}] \quad (11)$$

Periods to procure another new machinery and then manpower are computed using similar procedures as stated before. Consequently, Equations 9 and 10, respectively becomes 12 and 13 with the inclusion of parameter, u (counter for facility) which denotes number of additional facilities procured sequentially,

$Mac\_x_2 = Mac\_ x_2 (1+q)^u$ (12)

$Man\_x_3 = Man\_ x_3 (1+s)^u$ (13)

If the production outputs from the current facilities cannot meet the target demand within the time frame, the demand outside the planned time interval is likely to change. At this level, facilities on ground may need review. Therefore, Equation 14 may be appropriate to project the demand (if linear regression trend is assumed on past demand data). Thus,

$QD(t) = d + ft$ (15)

Where QD(t) is the projected demand at time, t, d and, f, are regression coefficients obtained from the past data, and, t, is the projected time.

3. Model Testing/Implementation

The model is tested with data obtained from a wire and cable industry in Nigeria. The company is producing copper (Cu) and aluminium (Al) cables. The information obtained on the machine and manpower quantities used for production of Cu and Al cables are summarised in Table 1 on yearly basis with quantity demanded, produced and the output contributions per machinery, and per manpower respectively, from 2003 to 2007. The machinery utilised in the company are adequate to perform necessary cable production functions which included drawing, stranding, cabling, extruding, coiling, rewinding and quality control.

Table 1: Quantity Demand and Outputs from Machinery and Manpower

Year	*Product*	*Number of manpower*	*Number of machinery*	*Quantity demanded (km)*	*Quantity produced (km)*	*Quantity Produced/Machinery*	*Quantity Produced/Manpower*
2003	Cu	19	6	6400	339	17.80	56.60
	Al	11	4	3600	191	17.36	47.75
2004	Cu	22	8	7232	486	22.09	60.95
	Al	13	4	4068	274	21.08	68.50
2005	Cu	26	8	7040	556	21.38	69.50
	Al	14	5	3960	314	22.43	62.80
2006	Cu	24	7	6572	532	22.17	76.00
	Al	19	8	4928	418	22.00	52.25
2007	Cu	25	8	5850	575	23.00	71.88
	Al	25	8	5850	575	23.00	71.88

The cost of obtaining unit machinery (machine, factory space, and raw material), X_c, Y_c is estimated to be 20 million Naira shared 15 and 5 million Naira, respectively between machine and raw material with factory space inclusive. The cost of utilising additional manpower, Z_c is estimated to be 2 million Naira (₦) (₦ is the symbol for Nigeria Currency). The monthly interest on deposits in most of the financial institutions of Nigeria is 8% (that is j= 0.08) and the inflation rate is about 21% on average (that is, k = 0.21). The company is making an average profit of 1 million per month. The linear regression results using SPSS (Statistical Packages for the Social Sciences) software relating the quantities of Cu and Al cables produced based on the data in Table 2 are given in Figures 2- 5.

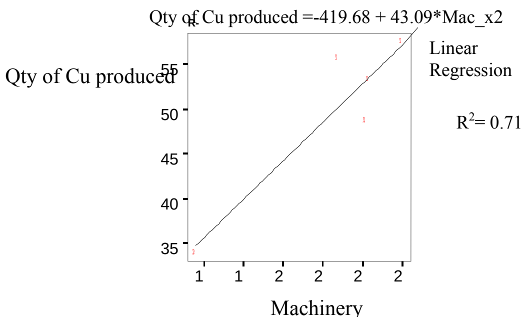

Figure 2: Relationship between Cu Cable Produced and Machinery

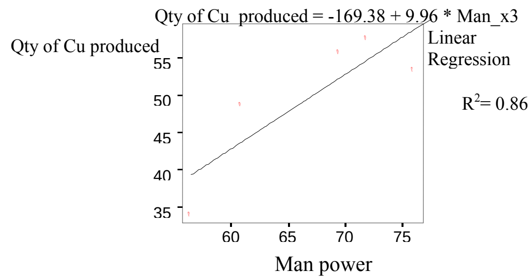

Figure 3: Relationship between Cu Cable Produced and Manpower

From the scatter plot in Fig 1 the model generated for the contribution of machinery to the projected copper cable output is

$$QP_m(t) \text{ (copper)} = -419.68 + 43.09*Mac\_x_2 \quad (16)$$

From the scatter plot in Figure 2 the model generated for the contribution of manpower to the projected copper cable output is

$$QP_w(t) \text{ (copper)} = -169.38 + 9.96*Man\_x_3 \quad (17)$$

The effect of manpower and machinery on Cu cable output is shown in Table 2

Table 2: Effect of Manpower and Machinery on Quantity of Copper Produced

Model	*R*	*R Square*	*Adjusted R Square*	**Std. Error of the estimate**
1	.955[a]	.912	.824	39.69321
		Model Summary a. Predictors: (Constant), Manpower, Machinery		

R^2, 0.912 in Table 2 shows that 91.2% of variation in quantity produced of Copper can be explained by the independent variables in consideration (Manpower and Machinery). The regression model is given in Equation 18

$$QP(t) \text{ (Cu)} = -439.551 + 30.882* Mac\_x_2 + 4.177* Man\_x_3 \quad (18)$$

The Scatter plot showing the contribution of machinery to Al cable production is shown in Figure 3, and that of the contribution of manpower is in Figure 4; the regression equations for the two are presented in Equations 19 and 20, respectively.

$$QP_m(t) \text{ (Al)} = -419.68 + 43.09 * Mac\_x_2 \quad (19)$$

$$QP_w(t) \text{ (Al)} = -116.33 + 7.76 * Man\_x_3 \quad (20)$$

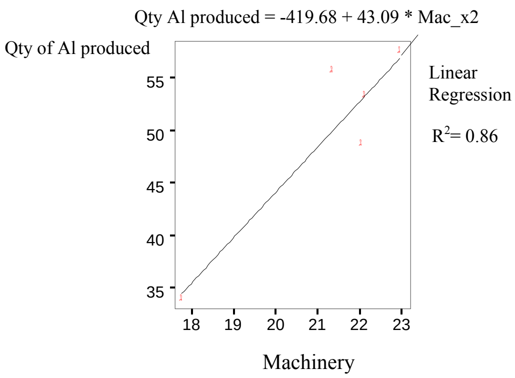

Figure 4: Relationship between Al Cable Produced and Machinery

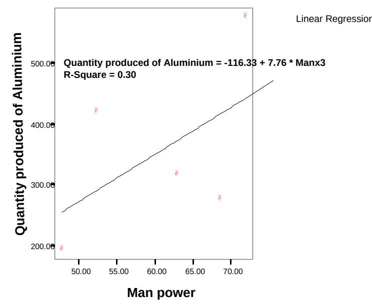

Figure 5: Relationship between Al Cable Produced and Manpower

Table 3 and Equation 21 respectively show the contributions of both machinery and manpower to overall Al output with R^2, 0.608, which shows that 60.8% of variation in quantity of Aluminium (Al) produced can be explained by the independent variables in consideration (Manpower and Machinery). The regression model is

$$QP(t)\ (Al) = -733.387 + 51.286 * Mac\_x_2 + 0.031 * Man\_x_3 \qquad (21)$$

The factory expansion is possible at time $t = t_n$ at which fund is enough to procure another unit set of facility. The monthly, n accumulated profit results based on Equations 6-14 of obtaining new sets of facility, u are presented in Tables 4 and 5

Table 3: Effect of Machinery and Manpower on Quantity Produced of Aluminum

Model	*R*	*R Square*	*Adjusted R Square*	**Std. Error of the estimate**
1	.780[a]	.608	.216	130.96368
Model Summary a. Predictors: (Constant), Manpower, Machinery				

Table 4: First Step Sequential Procurement of Facilities (j=8% k= 21%)

Month, n	*Cost of procuring machine with factory space (₦)*	*Cost of purchasing raw materials with factory space (₦)*	*Cost of manpower with factory spa=ce (₦)*	*Left over (₦)*
1	1,080,000			
2	2,473,200			
3	4,378,989			
4	8,429,989			
5	13,734,777			
6	20,643,140	5,643,140	643,140	
7			694,591	
8			1,5,90,614	
			2,776,761	776,761

The results in Table 4 and 5 have shown that it is possible to procure at least unit, u set of facility within unit year, t. Then the errors in the system (that is, between the target demands and outputs for Cu and Al cables) are determined based on Equation 1 under the assumption that the target demand is stable during the periods (though the demand may also be projected using Equation 15); and the results are presented in Table 8, from the base year 2007 with fifty-fifty output contributions from both machinery and manpower. The table further presents the glimpse of the results from Equations 16, 17, 19 and 20 based on the contributions of machinery and manpower to the Cu and Al outputs, separately. The projected expansion factors (for the subsequent years) for the industry's facilities including factory's building, machines, raw material, and manpower are also presented in the table.

Table 5: Second Step Sequential Procurement of Facilities (j=8% k= 21%, Φ= ₦776, 761)

Month, n	*Cost of procuring machine with factory space (₦)*	*Cost of purchasing raw materials with factory space (₦)*	*Cost of manpower with factory space (₦)*	*Left over (₦)*
1	1,918,902			
2	3,379,214			
3	5,357,278			
4	8,017,516			
5	11,575,300			
6	16,312,025	1,416,987		
7		2,837,146		
8		4,771,844		
		7,385,227	2,385,227	385,227

Table 6: Demands/outputs (Cu and Al cables) Control System and Expansion Factor From Year 2007

Year, t/ expans-ion unit, u	*Mac_x_2*	*Man_x_3*	*Quantity Demand QD(t)*	*Quantity Produced QP(t)(Cu)*	*Control Error E(t) (Cu)*	*Expansion factor [QP(t)/ QD(t)] (Cu)*	*Quantity produced, (km) QP(t) (Al)*	*Control Error E(t) (Al)*	*Expansion factor [QP(t)/ QD(t)] (Al)*
1, 2007	23	71.88	5850	540.09	5309.90	0.09	397.13	5452.87	0.07
2, 2008	33	107.82	5850	1029.92	4820.08	0.18	962.39	4887.61	0.16
3, 2009	49.5	161.73	5850	1755.39	4094.61	0.30	1794.89	4055.11	0.30
4, 2010	74.25	242.59	5850	2866.74	2983.26	0.49	3082.12	2767.88	0.53
5, 2011	111.37	363.89	5850	4519.75	1330.25	0.77	4989.61	860.39	0.85
6, 2012	111.37	545.84	5850	6999.57	-1149.57	1.19	7851.37	-2001.37	1.34

4. Discussion of Results

The implementation of the model in a wire and cable industry in Nigeria shows that the expansion of the industry's building varies with types of products, size of output, machinery and manpower, which are independent variables. The results generated from the gradual funding model using company's monthly profits show that enough fund could be generated within a year (at least 8 months) for the procurement of new production facility (Table 6). Production of copper cable took a lion share of the production output duration of meeting the demand target in all stages, thereby attracting high industrial building space in the next 3 year. However, aluminium cable took over the lead in the further 3 years of the production. The findings show that the expected capacity of aluminium cable production demands less building space in the first three years than copper and more building space in the last three years. The phenomenon is attributed to unstable expansion factors in the system. The analysis further shows that there are strong relationships between machinery, manpower, production output and building space on the production of both copper and aluminium cables (R^2, 0.608 and 0.912, respectively) (Tables 2 and 3). However, the relationships between aluminium product and manpower, machinery are separately weak and strong (R^2, 0.30, 0.86, respectively) (Figures 4 and 5), while that of copper's, are separately strong (R^2, 0.71 and 0.86, respectively) (Figures 2 and 3). This indicates that the expansion trend of industry's building for the production of both aluminium and copper can best be expressed completely in terms of the independent variables considered. This makes the model to have potential in solving the problem posed by funding on the development of industry in developing economy.

5. Conclusion

This study has successfully modeled a system that shows how magnitudes of manpower and machinery have influenced the sizes of both output and factory space. A dynamic funding model was provided to achieve the goal of sequential development of basic industrial resources devoid of any shortage in production outputs in meeting the target demand. In the model the quantity produced (output) was controlled by the sizes of machinery and manpower which in turn determined the building space. The three parameters of control namely, industry's output, machinery and manpower were modeled using multiple regression method.

The implementation of the model in a wire and cable industry in Nigeria showed that the expansion of the industry's building varied with types of products, size of output, machinery and manpower. The findings from the multiple regression models established a strong relationship between machinery, manpower, production output and building space on the production of both copper and aluminium cables. Relationship between aluminium product and manpower, machinery, are separately weak and strong, respectively, while those of copper's are separately strong. These correlation outcomes made regression models to be good predictors of future expansion of industry's building for the production of both aluminium and copper. The gradual funding programme established on monthly profit basis was adequate in providing a new set of facility within a year. Based on these findings, the model has potential in solving the problem of industrial development due to funding in developing economy.

6. References

Aderoba, A.A. (1997). "A sequential model for concurrent expansion in machinery and building using reinvestment earning". *Journal of Integrated Manufacturing System,* Vol. 8, No. 4, pp. 96-103.

Akanbi, O.G., Oluleye, A.E., and Onanuga, M. A. (2001). "Inventory model for deteriorating items with inflationary factors". *Nigeria Journal of Engineering Management,* Vol. 2, No. 1, pp. 28-34.

Folayan, O., Adeyemo, A., and Tayo, F. (1986). *Manpower Development and Utilization in Nigerian. (Problems and Policies),* University Press, Lagos.

Havper, W.M. (1991). S*tatistics*, 6th edition, Pitman Publishing, London.

Idris, M.O., and Aderoba, A.A. (2001). "An integrated investment model for new jobshops". *Nigerian Journal of Engineering Management,* Vol. 1, No. 2, pp. 38-46.

Kiyoshi, S. (1987). *The New Manufacturing Challenge (The Techniques for Continuous Improvement),* The Free Press, New York.

Oyekan, A. (2000). *Industrial Relations and Collective Bargaining in Nigeria*, Fedec & Company Ltd. Lagos.

Richard, J. S. (1986). *World Class Manufacturing (The Lessons of Simplicity Applied)*, Macmillan International, New York.

Richard, J.S. (1982). *Japanese Manufacturing Techniques*, Macmillan International., New York.

Richard, T. I. (1988). *Just-In-Time Manufacturing*, McGraw-Hill Inc., New York.

Sundrum, R.M. (1990). *Economics Growth in Theory and Practice,* Macmillan International, New York.

Teriba, O., Edozien, E.C., and Kayode, M.O. (1981). *The Structure of Manufacturing Industry in Nigeria,* University Press, Ibadan, Nigeria.