Minimising the Supervision Costs of the Organizations

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Abstract: - An Organisational structure is necessary as a framework for organising, planning, coordinating controlling and directing the organisational activities to achieve organisational goals Consequently, the organisational design problems have been formulated as that of minimisingcosts associated with supervision and coordination subject to some constraints with a heuristics as solution procedures. The difficulty of verifying the effectiveness of such heuristics in producing optimal organisation structures has created model acceptability problems. In this study, the concept of organisational work dynamics was used to reformulate supervision-cost function of a business organisation. Using this function, a dynamic programming version of the organisational design problem was defined and an associated algorithm developed. The performance (effectiveness and efficiency) of the algorithm was then compared to that of the existing heuristic. Also compared are the supervision-cost-based designed organisation structures and the existing organisational structure.

Keywords: - *Dynamic programming, Cost Reduction, Organizational Design, Organizational structure, Supervision Costs.*

i. INTRODUCTION

Most aspects of man-machine work systems have been designed using engineering principles with productivity improvement as the primary design criteria. Process design, operation design and facilities design appear to have received the good engineering attention, while, the design of organisation structure, the most important component of the work system that interrelates with others, has not received much engineering attention[1]. It is the human that develops the policies, plans and strategies for achieving organisational goals, decides on the skills, number of personnel per skill, materials, information, energy and machines combination to produce the goods and services with maximize productivity. The need for efficient utilisation of human work calls for a good labour organisation structure to achieve desired goals [2].

Consequently, different types of corporate governance structures and design tend to evolve across the globe [1,2,3,4]. The challenge of organisation design is to analyse and find the most suitable structure and design that will result into optimum performance and outcome of the constituting tasks such as control, planning, administration, monitoring, communication, maintenance and to a certain degree contracting [5].

Robbins and Coulter [3] defined organisational design as the process by which job/tasks are divided, grouped and coordinated for efficient and effective operations. Hinings and Greenwood [6]; Horling and Lesser [7]; Miller [8] and Robert [3] share similar views. The structure may be seen as a framework for decision making, the network for transmitting such decisions to the point where they are translated into action. An ideal structure should aid flow of information, materials, and tools, maximize personnel utilisation and minimize personnel redundancy for higher productivity

Some firms select their business organisational structure on the premise that structures evolve naturally (natural evolution), a "bench-marking" approach, that allows owners of business to adopt structures of other establishments on the conviction that what is working for establishment A is also good for B. In such cases, organization's structure design decisions are based on subjective opinion, intuition, and expert opinion. Other firms and researchers designed structures contingent on the data for the business situation (contingency approach). For years, it is the evolution theory that governed the process of specifying the structure of business organisations. In a more recent practice, the selection is restricted to a wide range of distinct forms of organisational structures identified by organisational scholars. Hax and Majluf, [2] explained that this school of thought lasted because "the present day organisational theory is 'soft' and largely lacks a quantitative structure that would lend itself to mathematical models."

It appears that the natural evolution approach to specifying a business organisation structure may not be adequate for a number of business situations. For example, knowledge-based economies, complexity and dynamism of business environments, and customers' behaviours have made simple selection of structures unsuitable. Some contingency factors were cited as being responsible [9]. Customers are no longer satisfied with standardized products; instead, they seek products and services that provide unique and desirable experiences. The application of scientific procedure, which considers the unique circumstances like the vision and goals of an organisation together with contingent data to specify an organisation structure, is formal design [10,11].

In designing organisation, concepts such as task, management coordination, and organization are framed into the design of the organisation structure [12,13,1,2,7]. The emphasis is on standardization of work, output, skills and supervision,. This is done by breaking down the tasks into elements at every workstation and measuring the available work in terms of time unit.

Charles-Owaba[13] formulated and solved the organisational design problem using the Operations Research paradigm with supervision cost as the objective function; the span of control, the number of management levels, number of managers/supervisors per level were the design variables while the number of the lowest cadre of personnel and human interaction dynamic factors were the design parameters. Large-scale applications of the model were not reported. One possible reason may be that the existing solution procedure, being a heuristic, cannot guarantee an optimal organisation structure. Associated with every heuristic is a problem of verifying model effectiveness and acceptance. People will accept a design model when they can easily verify that it is the best they are getting. The objective of this study is to reformulate the supervision cost model for organisational structure design, as a dynamic programming model and develop a solution procedure that guarantees optimal organisational structures with lowest supervision related costs.

ii. NOTATION

A_{ij}: Number of hours per day by the worker at j^{th} position of the ith level of the organisation in hours.

b_{ij}: Hourly rate of worker/decision maker at j^{th} position of the ith level of the organisation in ₦/hour

K_{ij}: The span of control is the number of subordinates at $(i-1)^{th}$ level that reports directly to boss at the jth position of the ith level of the organisation.

L_{ij}: This is the average number of cases in for the attention of decision maker/boss at $\mathbf{j^{th}}$ position of the ith level of the organisation.

$\overline{L}_{ij}$: This is the average number of cases that waited for the attention of decision maker/boss at $\mathbf{j^{th}}$ position of the ith level of the organisation.

M: The highest level of the entire organisation for which $N_i = 1$

N_{ij}: This is the number of positions of the jth type at the ith level of the organisational structure. This may be number of functional or divisional (j) managers or supervisors at the ith level of the organisation i=0,1, 2,M

N_{0j}: Number of operation positions of jth type at the 0th level of the organisation

NL: Number of management levels of the entire organisational structure

NM: This is the number of positions at levels 2 and above of the organisational structure

NS: Number of first level managers or supervisors of the organisational structure

S: Organisational size is the total number of positions of the completely organisational structure.

SC: Average Span of control of managers is the number of subordinates per level.

S_0: Operation position size of the organisation

W_{ij}: This is the average waiting time of cases (from subordinate and the boss's superior) that came for the attention of the boss at the jth position of the ith level of the organisation.

λ_{ij}: This is the rate at which the boss at the jth position of the ith level of the organisational structure .is consulted by the subordinates.

μ_{ij}: This is the rate at which the boss at j^{th} position and i^{th} level attend to cases that came for his attention.

ρ_{ij}:   This is ratio of the cases' arrival rate to the service rate of cases for the boss at j^{th} position and i^{th} level. This is the measure of information traffic intensity between each boss at j^{th} position of the ith level and his subordinates a $(i-1)^{th}$ levels and his superior at the $(i+1)^{th}$ level of the organisation.

f_i Annual supervision related cost function of ith level of organisational structure.

F Annual supervision costs of operating the whole organizational structure.

iii. ASSUMPTIONS

1. Every employee is of normal health, highly motivated and at least, has one job to perform in the organisation;
2. The chance that personnel in a work unit will work most harmoniously is highest when the authority and responsibility to control the activities of the unit is assigned to one and only one boss at any given moment;
3. Standard workload (that is suitable for the position) and not maximum possible workload is assigned to every staff;
4. The organisation is a non-fully automated business organisation.
5. It is a personnel-personnel or personnel-machine interaction, stochastic and dynamic decision and operation work system;
6. The workload of a boss (superior) at decision center is proportional to his/her span of control (K_{ij});
7. Requests, response to directives, situational reporting, classifications, authorizations, counseling are features of superior-subordinate relationships;
8. Arrival of cases for and departure from the boss are stochastic events; which follows (FIFO) First come, first served consultation discipline;
9. The superior is experienced enough to handle a decision center. Otherwise, there will be a large heap of cases at every moment;
10. Data for parameter estimation are collected from the interaction stochastic and dynamic system, when it has passed from the transient to a steady state;
11. The time a case leaves its location and travels to the superior's desk is negligible.

iv. SUPERVISION COST FUNCTION FORMULATION

We considered a work dynamic system, which idealizes a business activity. A known number of workers report for work at the same time and work for a fixed number of hours daily. At the resumption hour, workers arrive, clock in and report to their respective duty posts. Assuming the one boss structure, each worker starts work if all necessary information and materials (assignments reports, authorizations, clarification, counselling, procedures, energy, funds, helper, and facilities) are available. When very essential information or material is not available at the duty post, he/she consults the unit's boss for it. He/she may be lucky to meet the boss at the time, obtain the required information, and return to work. Otherwise, he/she waits until the boss attends to his/her needs. Subordinates who earlier had consulted the boss may have other needs later. At the time of need, each worker consults the boss for it and may get the attention of the boss immediately or later, depending on whether the boss is free at the time.

In general, a superior may call emergently on his subordinate for meetings, report submission and discussion, some conflict resolution or other administrative reasons. These transactions leave the superior/subordinate in one of the many modes: telephone, memo/letter, e-mail, radio messages, close circuit television, computer, personal appearance, etc. We note here that there is human dynamics or action prompted by the requirements for some essentials or work information or materials.

Associated with these personnel activities are some form of costs, which we will call supervision costs. These are expenditures on personnel for salaries, fringe benefits, welfare packages and/or time spent waiting for materials, facilities information, etc. The goal of this section to develop a supervision costs model as function of human dynamics and organisational structure variables that is amenable to dynamic programming solution methods that will guarantee optimal structure.

Consider an organisation structure consisting of $j = 1, 2, 3, ..., J$ positions and $i = 1, 2, 3, ..., M$ decision levels. When $i = 0$, it is the level for the lowest cadre of workers; $i = 1$, it is the supervisory level; $i > 1$, it is pure decision position as depicted in Fig 3.1.
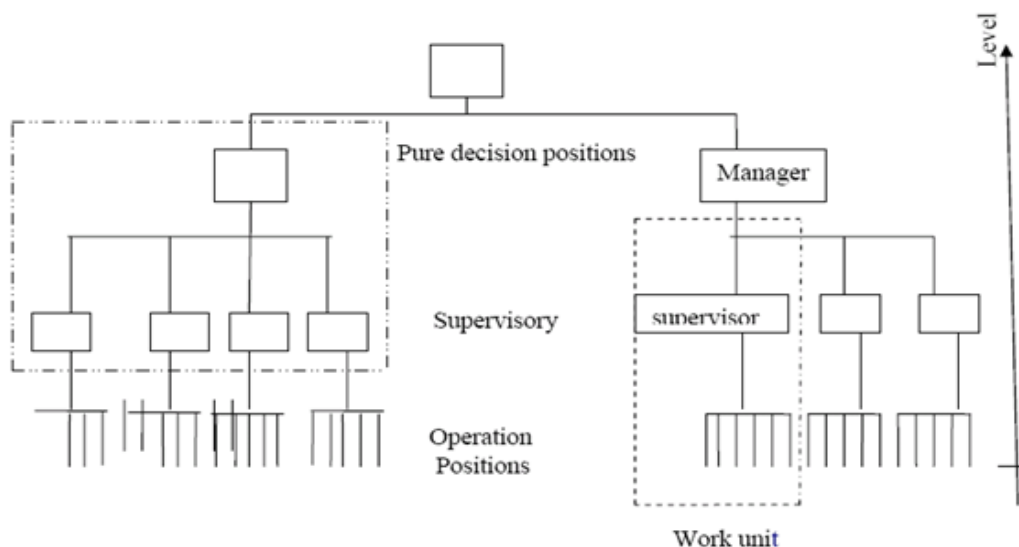
Figure 1 Organisational work units

For the work unit (Fig.1) at the jth position of the ith level with span of control (number of subordinates K_{ij}). The boss can be viewed as a server in a queuing system with finite source (K_{ij} subordinates under the boss). We consider the costs of wastes arising from the supervision and coordination activities in the organisational unit. These are costs of waiting time of the subordinates and idleness of the boss. The Supervision Cost is a hidden cost of lost times by the subordinates while waiting for the attention of the boss and the idle time of the boss who has very little job to do. For a work unit at i^{th} level and j^{th} position, the daily super vision cost DSC_{ij} is

$$DSC_{ij} = [b_{i-1,j}W_{ij}L_{ij} + b_{ij}P_{ij}A_{ij}] \quad \text{.......................................} (1)$$

where:

$b_{i-1,j}W_{ij}L_{ij}$ is the daily cost of waiting for the attention of the boss.

$b_{ij}P_{ij}A_{ij}$ is the daily cost of idleness of the boss.

Using queuing theory we can define $P_{ij},\ L_{ij}$ and W_{ij} [14]

The probability that no case require the attention of the boss (the boss is idle) is

$$P_{ij} = [\sum_{n=0}^{1} C_n^{K_{ij}+2} n! \rho_{ij}^n + \sum_{n=2}^{K_{ij}+2} C_n^{K_{ij}+2} n! \rho_{ij}^n]^{-1} \quad \text{.................. ....} (2)$$

The average number of cases which came during the considered time A_{ij} to receive the attention of the boss at position j of ith level is given by

$$L_{ij} = \sum_{n=0}^{K_{ij}+2} nP_{(n)ij} = \sum_{n=0}^{K_{ij}+2} C_n^{K_{ij}+2} n! \rho_{ij} P_{ij} \quad \text{...............................} (3)$$

The average number of cases (type 1 and type2) which waited during the considered time A_{ij} to receive the attention of the boss at position j of ith level is

$$\bar{L}_{ij} = \sum_{n=2}^{K_{ij}+2} (n-1) C_n^{K_{ij}+2} n! \rho_{ij} P_{ij} \quad \text{......................................} (4)$$

The average waiting time of cases at position of the boss is

$$W_{ij} = \frac{L_{ij}}{\hat{\lambda}_{ij}} = \frac{L_{ij}}{\lambda(K_{ij} - L_{ij})} = \left(\frac{\breve{L}_{ij} + 1 - P_{ij}}{\mu_{ij}(1 - P_{ij})} \right) \quad \text{.....................} (5)$$

The traffic intensity $\rho_{ij} = \dfrac{\lambda_{ij}}{\mu_{ij}}$ .... (6)

We define a fair structured organization as one in which the personnel at the same level carry the same responsibilities and reward. For a fair structured organization

$K_{i,1} = K_{i,2} = ... = K_{ij} = ... = K_i$ .... (7)

$\lambda_{ij} = \lambda_i,$ and $\mu_{ij} = .\mu_i.$ .... (8)

$$N_i = \sum_{J=1}^{J} N_{ij} = \frac{N_{i-1,}}{K_i}$$ .... (9)

The annual supervision cost at the ith level of a structured organisation is

$f =^\wedge y.DSC_i = yN_i[b_{i-1,}W_iL_i + b_iP_iA_i]$ .... (10)

The total annual supervision cost of the ith level of the organisation is given by equation 11.
The total annual supervision cost of the organisational structure with values of $P_{ij,} = P_i$ $L_{ij} = L_i$ and $w_{ij,} = w_i$ substituted is given be equation 12

$$f == \left(yN_i \left[\frac{\left[\frac{\sum_{n=2}^{K_i}(n-1)C_n^{K_i}n!\rho_i^n}{1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n} + \left[1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n\right]^{-1} \right]}{(1-\left[1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n\right]} \right] \frac{b_{i-1,}}{\mu_i} + \frac{b_iA_i}{1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n} \right) \dots\dots (11)$$

$$F = y\sum_{i=1}^{M} N_i \left[\frac{\left[\frac{\sum_{n=2}^{K_i}(n-1)C_n^{K_i}n!\rho_i^n}{1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n} + \left[1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n\right]^{-1} \right]}{(1-\left[1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n\right]} \right] \frac{b_{i-1,}}{\mu_i} + \frac{b_iA_i}{1+\sum_{n=1}^{K_i}C_n^{K_i}n!\rho_i^n} \dots (12)$$

The daily supervision cost of organisation (F) and organisational level (f) are functions of the design parameters: consultation rate of the subordinates at level (λ_i), the rate at which the boss attends to the cases (μ_i), the hourly pay of the workers (b_i), the number of operation positions N_0, the number of hours of work (A_i). F and f are functions design variables: number of positions at the level (N_i), the span of control K_i per level and number of organisational levels (M).

4.1 Function Behaviour

The total supervision cost function of an organisation F and total supervision cost function of organisational structure at any level i = 1, 2 …M f_i behaves as a convex function of span of control K_{ij} at that level with following properties:

1. It is a function of variables K_i and N_i and parameters $b_i, \lambda_i, \mu_i, A_i, N_0$) for all the levels i (i=1,2,3,…,M) (see figure 2).

2. $K_i = 2$ 3.., $\forall i$ i=1,2,3,.., (K_i is discrete)

3. F ,f_i are both strictly convex of a single variable function of K_i once N_{i-1} is known.

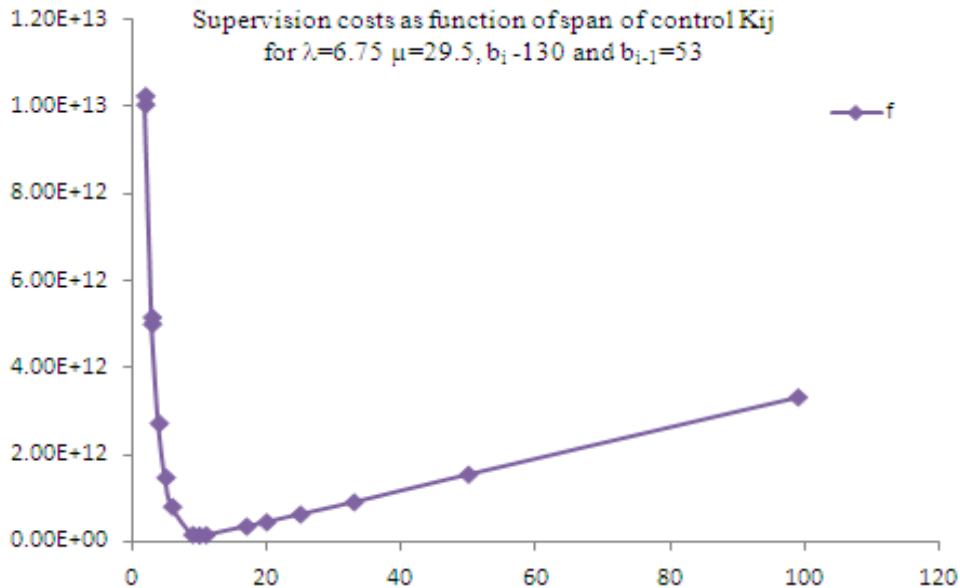F, f_i are increasing linear function of N_1 (see figure 2)

Figure 2 Supervision costs fi as function of span of control Ki

4.2 Supervision Cost Based Organisational Design Problem

Given the values of the parameter set θ determine the values for variables set $V = \{K_i, M, N_i\}$ such that the Daily supervision cost of the organisation is the minimum value.

Minimise $F = DSC = f(M, K_i, N_i, \theta)$ where DSC is as given in equation 12

Subject to the following organisational design constraints:

$N_{i-1} = N_i K_i$ .....Supervision Constraints

$N_M = 1$ Apex positions constraint

$W_i(K_i, N_i, \phi) \le A_{ij}$ Waiting time constraint

$N_i, K_i, M \ge 0$ None negativity constraints

4.3 The Heuristic Solution

The heuristics solution approach developed in Charles-Owaba (2002) is as outlined below:

Step 0: Determine the total number of operation positions N_0, of a particular organisation and the available hours of work A

Step 1: Set the level of organisation $i = 1$

Step 2: Determine the μ_i rate at which the boss attends to the subordinates and the rate at which the subordinates consults the boss, λ_i, for the level i

Step 3a: Substitute N_i with $\frac{N_{i-1}}{K_i}$ in DSC_i equation 11

Step 3b: Compute the values of DSC_i, functions for K_{ij} values 2,3,...... N_0 and determine the K_{ij} for which the value of DSC_i functions is minimum for DSC_i, and for which W_{ij} is less than A_{ij} and denote it as K_{ij}^*

Step 4: Determine the number of positions N_i at level i $N_I = \dfrac{N_{i-1}}{K_{ij}^*}$

Step 5: If $N_i = 1$ Go to Step 7

Step 6: Set $i = i + 1$ and go to step 2

Step 7: $N_M = \dfrac{N_{M-1}}{K_{Mj}^*}$ $N_M = 1$, $N_{M-1} = \dfrac{N_{M-2}}{K_{M-1,j}^*}$,................ $N_1 = \dfrac{N_0}{K_{1j}^*}$

Step 8: END

v. DYNAMIC PROGRAMMING DP APPROACH

The general dynamic Programming approach to problems is to optimize in stages.

We denote the level of the organisation as the stages with the span of control K_i as the stage variables and the number of positions at the level N_i as the stage decision variables.

The equation relating a stage to another is

$$F_i(i, N_i, K_i, \theta_l) = f_i(i, N_i, K_i, \theta_l) + F_{i-1}^*(i-1, N_{i-1}^*, K_{i-1}^*, \theta_{l-1})$$

Where

- $F_i(i, N_i, K_i, \theta_l)$ is the value of the criterion function (Daily Supervision Cost DSC) up to the level i^{th} of the organisation for any pairs of feasible of N_i and K_i (i.e. all N_i and K_i for which $N_i K_i = N_{i-1}$ and $W_{ij}(N_i, K_i, \theta_i) \le A_i$)

- $f_i(i, N_i, K_i, \theta_l)$ is the value of the criterion function (Supervision Cost DSC) at the ith level of the organisation, for any pair of feasible of N_i and K_i (i.e. $N_i K_i = N_{i-1}$ and $W_{ij}(N_i, K_i, \theta_i) \le A_i$)

- $F_{i-1}^*(i-1, N_{i-1}^*, K_{i-1}^*, \theta_{l-1})$ is the minimum value of the function at the stage $i-1$

- N_{i-1}^*, K_{i-1}^*, are the optimal values at the $i-1$ stage of number of positions and span of control respectively

5.1 Dynamic Programming Algorithm for Supervision CostMinimisation

Step 1: Set $i = 0$ Determine the number of operation positions for each work type N_{0j} Compute the supervision cost at o^{th} level as $f_0^* = 0$ since there is no supervision that level. Allow a small integer variation of about (DX<3) on N_{0j} to ensure that enough factors of N_0 are available for consideration especially when N_0 is a prime number (Note: that N_i x $K_i = N_0$)

Step 2: Set $i = 1$ Determine the set of pairs of N_1 and K_1 for which

$$N_0 - DX \le N_1 K_1 \le N_0 + DX \quad \forall \quad K_1 = 2, 3, 4, \dots\dots N_0 \text{ and } W_1(N_1, K_1, \theta) \le A$$

Step: 3. For each pair of N_{1j} and K_{1j} determined in step 2. Compute the waiting time $W_1(N_1, K_1, \theta_1)$ using equation 5. If $W_1(N_i, K_i, \theta_i) > A_1$ Discard the pair of N_i and K_i otherwise. Compute the supervision cost $f_i(N_i, K_i, \theta_i)$ for all the feasible pairs of N_i and K_i using equation 12

Step: 4 For every N_i and K_i pair whose $f_i(N_i, K_i, \theta_i)$ was determined in step 3 Calculate the $F_i(N_i, K_i, \theta_l) = f_i(N_i, K_i, \theta_l) + F_{i-1}^*(N_{i-1}^*, K_{i-1}^*, \theta_{l-1})$ Write out for every N_i, and all the $F_i(N_i, K_i, \theta_l)$ and $K_i s$ corresponding to each $F_i(N_i, K_i, \theta_l)$ Determine for every N_i the minimum $F_i(N_i, K_i, \theta_l)$ in the case of supervision cost and denote it as $F_1^*(N_i, K_1^*, \theta_l)$ Note also the value of K_1^* corresponding to the $F_1^*(N_i, K_1^*, \theta_l)$

Step;5 Determine the minimum $F_1^*(N_i, K_1^*, \theta_l)$ for all the N_i at the i stage and denote it as $F_1^{**}(N_i, K_1^*, \theta_l)$ If $F_1^{**}(N_i, K_1^*, \theta_l)$ corresponds to $N_i = 1$, Go to step 10 If $F_1^{**}(N_i, K_1^*, \theta_l)$ corresponds to $N_i \ge 2$ Note $F_1^*(N_i, K_1^*, \theta_l)$ for $N_i = 1$ at this stage and denote as $L*(N_i)$ and note its K_1^* value

Step:6 Set $i = i + 1$ Determine the feasible pairs of Ni and K_{ij} for which $N_i K_i \in \{N_{i-1}\}$

Step:7 For each pair of N_1 and K_1 determined as feasible in step 6 Compute the waiting time $W_i(N_i, K_i, \theta_i)_j$ using equation 5. If waiting time $W_i(N_i, K_i, \theta_i) > A_i$, Discard the pair of N_i and K_i otherwise compute the supervision costs $f_i(N_i, K_i, \theta_i)$ for all the feasible pair of N_i and K_i using equation 3.40 $F_i(i, N_i, K_i, \theta_l) = f_i(i, N_i, K_i, \theta_l) + F_{i-1}^*(i-1, N_{i-1}^*, K_{i-1}^*, \theta_{l-1})$ for the feasible pair of N_i and K_i Write out for every N_i, and all the $F_i(N_i, K_i, \theta_l)$ and $K_i s$ corresponding to each $F_i(N_i, K_i, \theta_l)$ Determine for every N_i the minimum $F_i(N_i, K_i, \theta_l)$ in the and denote it as $F_1^*(N_i, K_1^*, \theta_l)$ Note also the value of K_1^* corresponding to the

$F_1^*(N_i, K_1^*, \theta_1)$ Determine the minimum $F_1^*(N_i, K_1^*, \theta_1)$ for all the N_i at the i stage and denote it as $F_1^{**}(N_i, K_1^*, \theta_1)$

Step: 8 If $F_1^{**}(N_i, K_1^*, \theta_1)$ corresponds to $N_{ij} = 1$, Go to step 10 If $F_1^{**}(N_i, K_1^*, \theta_1)$ corresponds to $N_i \geq 2$.

Denote $Fl_1^*(i, N_i, K_1^*, \theta_1)$ for $N_i = 1$ at this stage as $L^*(N_{i-1} = 1)$ and note its K_i value

Step: 9 Go To Step:6

Step: 10 If $F_1^{**}(N_i, K_1^*, \theta_1)$ for $(N_i = 1)$ is greater than L* (N_{i-1}) (if it exists) Go To step 12

Step: 11 $F_1^{**}(N_i, K_1^*, \theta_1)$ for $N_i = 1$ is the minimum supervision cost value of the organisational structure

- **i** is the number of level M
- $N_M = 1$
- $N_{M-1} = K_M^*$
- $N_{i-1} = N_i K_i^*$
- ……………………
- …………………
- $N_0 = N_1 K_1^*$.

Step: 12 **F** = **L*** (N_{i-1}) is the minimum total supervision cost value of the organisational structure

- $i - 1 = M$ is the number of level M
- $N_M = 1$
- $N_{M-1} = K_M^*$
- $N_{i-1} = N_i K_i^*$
- …………………
- $N_0 = N_1 K_1^*$.

Step:13 End

vi. APPLICATION

The principles and the methodology outlined in sections 2 to 5 were applied in the redesign of an existing manufacturing firm. Data were collected using the work measurement principles to determine the values of human work and operation positions (N_0), consultation rate of the boss to his superior (λ_1) and service rate (μ_i) at each level. The existing organisational structure is presented in table 1 in terms of number levels, number of positions per level and span of control per level. The values of the related parameters and other information are presented in table 1. The existing organizational structure has three departments with staff strength of 248: 46 decision positions; 204 operation positions and 4 organizational levels.

TABLE 1 Parameter values for Case 2

	hours	Cases/ hour			₦/ hour	Ni	Ki
Level	A	λ_{1i}	λ_{2i}	μ	b	Ni	Ki
4	8	.0.35	2..15	2.5	874..6	1	4
3	8	0.31	1.25	1.75	583.33	4	3
2	8	0.85	1.33	3.378	291.75	12	2
1	8	0.13	0.94	4.37	197.4	29	7
0	8	-	-	-	82.16	204	-
$N_0 = 145$							

vii. RESULTS AND DISCUSSION

The organisational structures and other characteristics of designs resulting from the solutions to design problem are presented in table 2 for dynamic programming and heuristic methods, as well as the existing structure. In addition, the DP algorithm and Heuristic computational times were curve fitted to and plotted against the Number of the operation positions in the organisations. The results are shown in expressions 14 and 15 and graphs presented in Fig.3.

$$T_{DP} = 0.000259199 - 0.0080021452 N_0 + 0.00035750721 N_0^2$$

$$- 4.38122 \times 10^{-6} N_0^3 + 4.980177 \times 10^{-8} N_0^4 \qquad \ldots\ldots\ldots\ldots (14)$$

and

$$T_H = -0.00363466 + 0.0250665 N_0 - 0.00020473 N_0^2$$

$$+ 7.6011868 \times 10^{-7} \qquad \ldots\ldots\ldots\ldots\ldots (15)$$

TABLE 2 Organizational characteristics for DP and H designed and the Existing organization

S/No	Organizational characteristics	Dynamic Programming (DP)	Heuristic (H)	Existing
1	Supervision cost ₦	2,093,510.00	2,572,371.27	
2	Number of levels	3	3.	4
3	Number of managers	4	5	17
4	Number of supervisors	18	21	29
5	Average span of control	5.6	4.6	4
6	Organizational size	167	171	248
7	Computation Time (seconds)	14.89	1.65	-

For the design criterion of minimising supervision cost, the Dynamic programming (DP) design algorithm produce smaller organizational structures as evident in the results presented in tables 2 The organizational size of the DP designed structure (167) was smaller than that of the heuristic designed (171) in the cases studied. The number of managers (4) and number of supervisors (18) for the DP are smaller than those of Heuristics designed (5) and (21) respectively. However, the average span of control of the DP-designed structure (5.6) is higher than the value (4.6) for the Heuristic-designed. The DP algorithm reduced the supervision cost from 2,572,371.27 units for Heuristic-designed to 2,093,510.00 units for DP-designed structures as indicated in table 2.

The reason for these differences is that DP algorithm, being an implicit enumeration, searches the entire solution space for the set of span of management, which will result in the global optimum for the design problem. The Heuristic, on the other hand, finds the optimal solution for each level and uses it as input to the next level. The optimal at stage 1 may induce sub optimality ant other stages. This is also evident in the solution values of all the objective function in which the values corresponding to the DP-designed structures are significantly better than those of the Heuristic designed (table2).

However, the computation time (14.89 seconds) for the implicit enumeration approach (the DP algorithm) is more than that of the Heuristic approach (1.65 seconds). It is clear from Fig.2, a plot of computation time and number of operation position that the DP algorithm time is polynomial function of the number of operation position N_0 for range (40-140) while the heuristic computation tine is quadratic function the number of operation position N_0 for the same range. These are shown in equations 13 and 15. At this range of operating positions, the DP algorithm is relatively efficient since the literature defines efficiency in terms of the degree of polynomial or exponential curves[15,16].

However, whether or not it is efficient, the computation time is only in seconds ranging between 0.1 and 15.0. Hence, barring memory problems, for even large problems, organizational design with the DP algorithm may be feasible on Personal Computers. Relative to the existing structures of the cases examined, the DP designed algorithm reduced the, number of management levels, managers, and supervisors' form 4, 17, and 29 to 3, 4, and 18 respectively (see table 2).
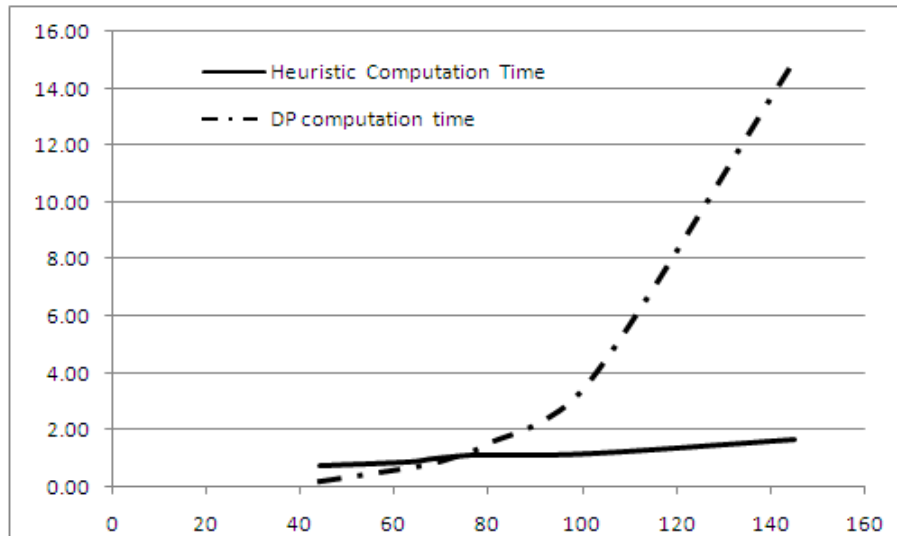
Figure 3 Computation times for Heuristic and DP algorithm

viii. CONCLUSION

Supervision cost function was defined in terms of the subordinate-superior consultation rate, superior-subordinate service rate, unit cost of emolument and number of the lowest cadre of staff as design parameters while span of control, number of management levels and managers per level are the design variables.

The organisational structures resulting from 'dynamic programming algorithm' design method have lower supervision cost, workforce and management levels than those produced using the existing heuristic. The application of supervision cost minimization criterion for organisational design produced structures with significantly lower workforce and number of management levels than existing organisational structure. The heuristic computational time was lower than that of the dynamic programming algorithm. Both computation times are less than 15 seconds..

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