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A Personnel Cost Model for Organisational Structure Design

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Abstract
In this paper, a business organisation's personnel related cost function was developed in terms of number of managers (NM), span of control (SC) per manager, number of supervisors (NS) and number of management levels (ML) as variables while number of lowest cadre of staff; rate of pay and allowances, working hours and human interaction dynamics factors were the parameters. Based on this, business organisational design problem was formulated and solved as nonlinear constrained optimization problem with the minimization of total personnel related operating costs, as the objective as the objective function. A solution methodology was produced and an example problem solved.
Keywords: Organisational design, Organisational structure, Optimal organisation, Personnel cost model

1. Introduction

The organisational structure design refers to the process of determining the type and number of technical activities; number of operational and management positions; the span of control; number of decision levels; number of positions at each level; and the communication channels required to ensure that the organisation functions effectively and efficiently and with highest productivity (Charles-Owaba, 2002)

In pursuant of the above, two main schools of thought guide an entrepreneur in the choice of a business organisation structure: natural evolution theorists and contingency theorists (Charles-Owaba, 2002; Dunbar and Starbuck, 2006). In the former, business organisational structure is selected on the premise that structures evolve naturally, while in the latter, they are designed contingent on the data of the business situation. For years, it is the evolution theory that governed the process of specifying the structure of business organisations. It is a "bench-marking" approach that allows owners of business to adopt a structure of other establishments on the conviction that what is working for establishment A is also good for B. 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 Majiluf (1981) 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."

However, knowledge-based economies, complexity and dynamism of business environments, and sophisticated customers' behaviour have made simple selection of structures unsuitable (Nadler and Tushman, 1997; Goold and Campbell, 2002; Russo and Harrison, 2005) . There appears to be too many contingency factors unaccounted for by this simple approach. For example, customers are no longer satisfied with standardized products; instead, they seek products and services that provide unique and desirable experiences (Robert 2004).

Furthermore organisational behaviour literature has established empirical relationship between decentralisation of decisions and such variables as size (Blau and Schoenherr, 1991; Child, 1973; Khandwalla, 1974). Other studies showed relationship between structure and strategy, (Mintzberg, 1981; Robert, 2004). Other factors against the evolution theory are global competition, free trade agreements, low cost of foreign labour and increasing customer's expectations, which required aggressive organisational transformations (Foote, Galbraith, Hopeand, and Miller, 2001; Sawhney, Balasubramania and Krishna, 2004; Kogut and Zander, 1992; Starbuck, 1992; Robert, 2004).

Even before these compelling reasons that strongly support the contingency school of thought. Hax and Majluf (1981) and Drucker (1974) had called for the application of the "Operations Research Paradigm of theory, alternatives, criteria, evaluation and choice" to organisational design. Similar feelings has been expressed in more recent time (Horling and Lesser, 2004; Davies and Brady, 2000). Charles-Owaba (1987, 2002) argued that an optimization approach to organisational design appears to be the only technique to adequately address demands of the present day business world, since the methodology has the following salient features:

- Explicitly stated objective functions which allow organisational design goals to be expressed mathematically;
- Design decision variables through which the desirable values of relevant elements of an organisation structure can be specified in the process of design procedure;
- A framework for identifying and estimating design parameters thereby allowing situation-data-based definition of real life organisational design problems;
- A framework for expressing design situational reality checks as well as owner's desirable limitations in form of mathematical constraints;

- Explicitly stated design criteria which guides the (direction) design procedure as well as serve as optimality indicator;
- A framework for mathematically stating the organisational design problem in a solvable manner;
- The existence of procedures capable of identifying, evaluating and selecting the best from all the alternative solutions to a design problem.

The foregoing clearly showed that Operations Research provides a general framework suitable for systematic and quantitative definition and solution to real life business organisational design problems, but only few work using this approach have been reported. Charles-Owaba (1987, 1998) used this approach for organisational design with 'Human utilisation', and' supervision cost' as objective functions respectively. In both cases, 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

These models did not reflect all the costs related directly to human activities in an organisation. Personnel emolument, a very important component of business organisational operating cost, is yet to be included as part of the design objective function and criteria. The objective of this study is to formulate a more encompassing organisational design model which produces organisational structures with lowest personnel relate costs in terms of known design variables; design parameters; shape, size and policy constraints and all possible personnel-related components of operating cost and then provide a solution procedure.

2. Organisational Design Theories

Hax and Majiluf (1981) proposed two main steps in organisational design: definition of a basic structure and design of the detailed structure. The first step deals with the strategic positioning of the firm (Charles-Owaba, 1987; Dunbar and Starbuck, 2006; Harris and Raviv, 2002) . The second is the detailed specifications of the structure. This work is concerned with second stage.

There are three basic business reported widely in literature (Docherty et. al., 2001): Functional, divisional and matrix structures. Both functional and divisional are hierarchies but defined respectively on the basis of inputs and outputs. The matrix organizational structure evolved from multi-dimensional profit reporting concepts.

Henri Fayol developed the universal approach or the administrative theory with the central idea that regardless of the nature of the organisation, there are certain universal principles that should be followed to obtain successful performance (Charles-Owaba, 1987, 2002; Fox, et al, 1998; Walonick, 2005). The operational approaches developed by Fredrick Taylor's (scientific management) deal with the management principles dedicated to improving efficiency, cutting waste, and improving quality (Bedeian, 1974; Kreitner, 2005).

The Human Relation theory states that "the performance of an organisation depends exclusively on the human characteristic and behaviour relative to individual needs, motivation, perception, attitudes, group behaviour and communication" (Charles-Owaba, 2002; Hax and Majiluf, 1981). The decision-Making theory views organisational structure as a set of decision-making units in a communication network (Charles-Owaba, 2002). The theory holds that organisational individual behaviour must be analyzed within the decision-making framework provided by organisational structure in the rational pursuit of its objectives (Fox, 1998). Both theories are important for this study.

The socio-technical approach advocates that equilibrium among the social system (people), the technical system (tools, techniques and knowledge), and the environment (customers and users) is necessary to make the organisation effective (Clarke, 2000). The contingency theory states that different environments require different organisational relationships, which must consider the various social, legal, political, technical and economic factors, for optimal effectiveness (Kreitner, 2005).

The contingency approach is an effort to determine through research which organisational practices and techniques are appropriate in specific situations. They hold that the traditional approaches to organisational design were not necessarily wrong, but inadequate, and that needed design theory and practices are in a contingency approach (Tosi and Slocum, 1984; Shetty, 1974).

3. Notation

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

b_{ij} : Hourly rate of worker/decision maker at j^{th} position of the i^{th} 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

j^{th} position of the i^{th} 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 i^{th} 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 i^{th} 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 j^{th} type at the i^{th} level of the organisational structure. This may be number of functional or divisional (j) managers or supervisors at the i^{th} level of the organisation i=0,1, 2,M

N_{0j} : Number of operation positions of j^{th} type at the 0^{th} 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 j^{th} position of the i^{th} level of the organisation.

λ_{ij} : This is the rate at which the boss at the j^{th} position of the i^{th} 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 i^{th} level and his subordinates a $(i-1)^{th}$ levels and his superior at the $(i+1)^{th}$ level of the organisation.

f_i Personnel related cost function of i^{th} level of organisational structure.

F This is the total daily costs of operating the whole organizational structure.

4. 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.

5. Personnel Cost function of organizational structure

An organisation structure usually consists of $j = 1, 2, 3, \ldots, J$ types of positions at $i = 1, 2, 3, \ldots, M$ decision levels. Level 0 (i = 0) consists of the lowest cadre of workers; level 1 (i = 1) is the supervisory level; while levels 2 and above (i > 1) are pure decision position as depicted in Figure 1. For a typical work unit (shown in Figure1) at the j^{th} position of the i^{th} level with one boss and K_{ij} subordinates (span of control). The boss can be viewed as a server in a queuing system with the jobs or cases being problems, clarifications, instructions, directions and so on, from finite source of K_{ij} subordinates under him or her.

We consider three cost components arising from the operation of such organisational unit on a daily bases: costs of waiting costs of the subordinates; cost of idleness of the boss and cost of personnel.

The cost associated with the time lost by the subordinates while waiting for the attention of the boss is the waiting costs. It is the cost of lost opportunity to perform the human work for which they are employed. If the pay rate of an individual worker receives is proportional to the amount of human work he delivers to the organisation, then we can estimate this cost per worker from the pay rate and time losses. Denoting this cost for a work unit at j^{th} position of the i^{th} organisational level as DCW_{ij}, then

$$DWC_{ij} = b_{i-1,j} W_{ij} L_{ij} \quad \ldots\ldots (1)$$

The second component is costs of idleness of a boss who has very few subordinates and so less than enough jobs to do. If we denote such cost for a work unit at the j^{th} position of the i^{th} organisational level as DIC_{ij}, then

$$DIC_{ij} = b_{ij} P_{ij} A_{ij} \quad \ldots\ldots (2)$$

This the cost associated with the daily pay of personnel in the work unit at j^{th} position of the i^{th} level, if we denote this cost for a work unit as DPC_{ij}, then

$$DPC_{ij} = b_{ij} A_{ij} \quad \ldots\ldots (3)$$

The total daily costs related to personnel operating the organisational work unit ($DPOC_{ij}$) is estimated thus

$$DPOC_{ij} = DWC_{ij} + DIC_{ij} + DPC_{ij} \quad \ldots\ldots (4)$$

$$DPOC_{ij} = (b_{i-1,j} W_{ij} L_{ij} + b_{ij} P_{ij} A_{ij} + b_{ij} A_{ij}) \quad \ldots\ldots (5)$$

The number of positions available at the i^{th} level of the organisation, N_i is

$$N_i = \sum_{j=1}^{N_j} N_{ij} \quad \ldots\ldots (6)$$

The daily personnel operating cost $DPOC_i$ for organisational structure at the i^{th} level, for $i \geq 1$ is

$$f_i = \sum_{j=1}^{N_I} (b_{i-1,j} W_{ij} L_{ij} + b_{ij} P_{ij} A_{ij} + b_{ij} A_{ij}) \quad \ldots\ldots (7)$$

At the operation positions, level, $i = 0$, since the positions have no subordinates, DCW_0, and $DCI_0 = 0$, but the daily personnel cost is given by

$$f_0 = \sum_{j=1}^{N_0}\left[b_{0j}A_{0j}\right] \quad \text{(8)}$$

The total daily costs of operating the whole organizational structure is given by

$$F = \sum_{i=1}^{M}\left[\sum_{j=1}^{N_i}\left[b_{i-1,j}W_{i,j}L_{i,j} + b_{i,j}A_{i,j}(P_{i,j}+1)\right]\right] + \sum_{j=1}^{N_0}\left[b_{0,j}A_{0,j}\right] \quad \text{(9)}$$

From the queuing analysis (Taha, 1986), we can infer the following:

1. The probability that no case is in the system of a server with a finite customer source K_{ij} at stability is proportion of time the boss has no case to attend to P_{ij} is given by

$$P_{ij} = [1 + \sum_{N=1}^{K_{IJ}} C_n^{K_{ij}}\, n!\rho_{ij}^n]^{-1} \quad \text{(10)}$$

2. The average number of cases, which waited during the considered time A_{ij} to receive the attention of the boss at position j of i^{th} level. is given by

$$\bar{L}_{i,j} = \sum_{n=1}^{K_{i,j}} (n-1)C_n^{K_{i,j}}\, n!\rho_{i,j}^n\, P_{i,j} \quad \text{(11)}$$

3. The average number of cases for the attention of the boss within the considered time A_{ij} is given by

$$L_{i,j} = \bar{L}_{i,j} + 1 - P_{ij} \quad \text{(12)}$$

4. The average waiting time cases at position of the boss at ij is given by

$$W_{ij} = \frac{L_{ij}}{\bar{\lambda}_{ij}} = \frac{L_{ij}}{\lambda_{ij}(K_{ij} - L_{ij})} = [\frac{\bar{L}_{ij} + 1 - P_{ij}}{1 - P_{ij}}]\frac{1}{\mu_{ij}}) \quad \text{(13)}$$

5. The traffic intensity is the ratio of consultation rate to the service rate

$$\rho_{ij} = \lambda_{ij} \big/ \mu_{ij} \quad \text{(14)}$$

5.1. Fair structured Organization.

By this we mean that managers or and supervisors at the same level of organization carry fairly the same level of responsibilities and work load. This implies that the following holds:

$$K_{i1} = K_{i2} = K_{ij} = K_i, \text{ and } \mu_{i1} = \mu_{i2} = \mu_{ij} = \mu_i,$$

$$\text{Also } \lambda_{i1} = \lambda_{i2} = \lambda_{ij} = \lambda_i, \text{ and } b_{i1} = b_{i2} = b_{ij} = b_i$$

Hence, the levels are related thus:

$$\frac{N_{i-1}}{K_{ij}} = \sum_{j=1}^{Ni} j = Ni \quad \text{((15)}$$

Substituting equations 10 – 14 into equation 7 and 9, will yield the following expressions respectively

$$f_i = DPOC_i = \sum_{j=1}^{Ni}\left(b_{i-1}\left[\frac{\left(\sum_{n=2}^{K_I}(n-1)C_n^{K_i} n!\rho_i^n + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n \right)^2}{\mu_i\left(\left(\sum_{n=1}^{K_i} C_n^{K_i} n!\rho_i^n \right) + \left(\sum_{n=1}^{K_i} C_n^{K_i} n!\rho_i^n \right)^2 \right)} \right] + b_i A_i \left(\frac{2 + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n}{1 + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n} \right) \right) \quad \ldots\ldots\ldots (16)$$

and

$$F = \sum_{i=1}^{M} N_i \left(\left(b_{i-1}\left[\frac{\left(\sum_{n=2}^{K_I}(n-1)C_n^{K_i} n!\rho_i^n + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n \right)^2}{\mu_i\left(\left(\sum_{n=1}^{K_i} C_n^{K_i} n!\rho_i^n \right) + \left(\sum_{n=1}^{K_i} C_n^{K_i} n!\rho_i^n \right)^2 \right)} \right] + b_i A_i \left(\frac{2 + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n}{1 + \sum_{n=1}^{K_I} C_n^{K_i} n!\rho_i^n} \right) \right) \right) + (N_0 b_{0,j} A_{0,}) \quad \ldots. (17)$$

$$f_I = f(b_{i-1}, b_i, \rho_i, K_i, \mu_i, \lambda_i, A_i, N_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

$$F = f(b_{i-1}, b_i, \rho_i, K_i, \mu_i, \lambda_i, A_i, N_i, N_0, M, b_0) \ldots\ldots\ldots\ldots\ldots (19)$$

The daily personnel related operating cost at the i[th] level of the organisation is a function of the parameters: consultation rate of the subordinates (λ_{ij},); the boss's service rate (μ_{ij}); the hourly pay at the positions b_{ij} ; the number of hours of work (A_{ij}); number of operation positions (N_0); number of positions per level (N_{ij}); the span of control (K_{ij}) and the number of levels (M)

6. Function Behaviour

The total Operating Cost Function of an organisation $\boldsymbol{F}$ and total operating cost function of organisational structure at any level i = 1, 2 …M $\boldsymbol{f_i}$ 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. $\boldsymbol{F}$, $\boldsymbol{f_i}$ are both strictly convex of a single variable function of K_i once N_{i-1} is known.
4. $\boldsymbol{F}$, $\boldsymbol{f_i}$ are increasing linear function of N_1 (see figure 2)

7. Organisational Design problem:

The organisational design problem is therefore, that of determining values of variables set V, given the values of parameter set θ such that personnel related cost of operating the organisation structure will minimum subject to

the constraints: number of workers supervising should be less than those being supervised (Supervision constraints), the overall boss should not be more than one (Apex position constraints), the waiting time should not exceed the hours of work (Waiting time constraint) and the none negativity constraints
The design problem is stated as thus:

Minimize $F = f(,M,K_i,N_i,\theta)$; where F is as given in equation 17

Subject to: following organisational design constraints:

$\sum_{j=1}^{N_i} K_{ij} \le N_{i-1}$ Supervision constraints

$N_M = 1$ Apex position constraint

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

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

8. The Solution Method

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 : the 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 $\frac{N_{i-1}}{K_{ij}}$ in F function

Step 3b: Compute the values of F, functions for K_{ij} values 2,3,…… N_0 and determine the K_{ij} for which the value of F_i, functions is minimum for $APRC_i$ 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 $N_I = \frac{N_{i-1}}{K_{ij}^*}$

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

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

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

Step 8: END

9. Application: The case of a tyre manufacturing company

A tyre manufacturing company in western Nigeria was studied by applying work-study tools to determine the parameter values. The existing organisational structure is presented in table 1, while the values of the related parameters and other information are presented in table 2. The existing organisational structure has three departments with staff strength of 248: 46 decision positions; 204 operation positions and 6 organizational levels

10. Results and Discussions

By applying the solution outlined in section 7 we obtained the organisational structure shown in table 3
Relative to the existing structures of the cases examined, Personnel cost functions reduced the value of number of management levels, managers, supervisors and the personnel related operating cost by 50.0%, 82.4%, 55.2%, -162.2% and 61.1% respectively and increased the average span of control by 162.2% as presented in Table 4..
The mean organisational size of 88.6 for the personnel operating cost minimization is less than 95 and 96 for the supervision cost minimization and personnel utilisation maximization respectively. The mean number of management level, supervisors and manager of 2, 6.4 and 1 for the personnel operating cost designed structures

is less than 2.47, 11.4 and 2.4 for the supervision cost, and 2.57, 12.3 and 3 for the personnel utilisation designed structures. The average span of control of 9.9 for the personnel operating cost minimization was also higher than 7.0 and 6.5 for supervision cost minimization and personnel utilisation maximization respectively. The effect of the above is lower mean personnel operating cost of N 18,845,987.978 for the personnel operating minimization relative to N 20,825,200.57 and N 21,411,221.29 for supervision cost minimization and personnel utilisation maximization respectively. These changes are significant as shown in Tables 4.
This may be because the personnel operating cost objective function encompasses both the cost of wastes and personnel emolument. Its minimization produces smaller structures capable of performing the organisational tasks with lowest overall personnel and waste cost.

11. Conclusion

Personnel related cost function for operating an organisational structure 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 personnel cost function estimates the costs associated with human interaction dynamics (idle and waiting cost) and the costs of personnel in an organisation. The application of personnel operating Cost minimization criterion for organisational design produced structures with significantly lower workforce and number of management levels.

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Table 1 Existing Organisational structure for tyre manufacturing company

Organisational level	Number of workers	Span of control
4	1	4
3	4	3
2	12	2
1	29	7
0	204	-
Personnel related costs: Organisational Size: 250		

Table 2 Parameter values for the tyre manufacturing company

	hours	Cases/ hour		₦/ hour
Level i	A	λ_i	μ	B
4	8	2.15	2.5	874..6
3	8	1.25	1.75	583.33
2	8	1.33	3.378	291.75
1	8	0.94	4.37	197.4
0	8	-	-	82.16
N_0 =145				

Table 3 Designed Organisational structure with minimum personnel cost

Organisational level	Number of workers	Span of control
3	1	2
2	2	8
1	13	11
0	145	
Personnel related costs: ₦ 42,949,433.48, Organisational Size: 161		

Table 4.Comparism of the designed and existing structures

Parameters	Existing	Designed	% Reduction
Number of levels	6	3	50.0
Number of managers	17	3	82.4
Number of supervisors	29	13	55.2
Average span of control	2.67	7	-162.2
Operating Cost	110,296,007	42,949,433.48	61.1
Management size	46	16	65.2
Organisational size	250	161	35.6

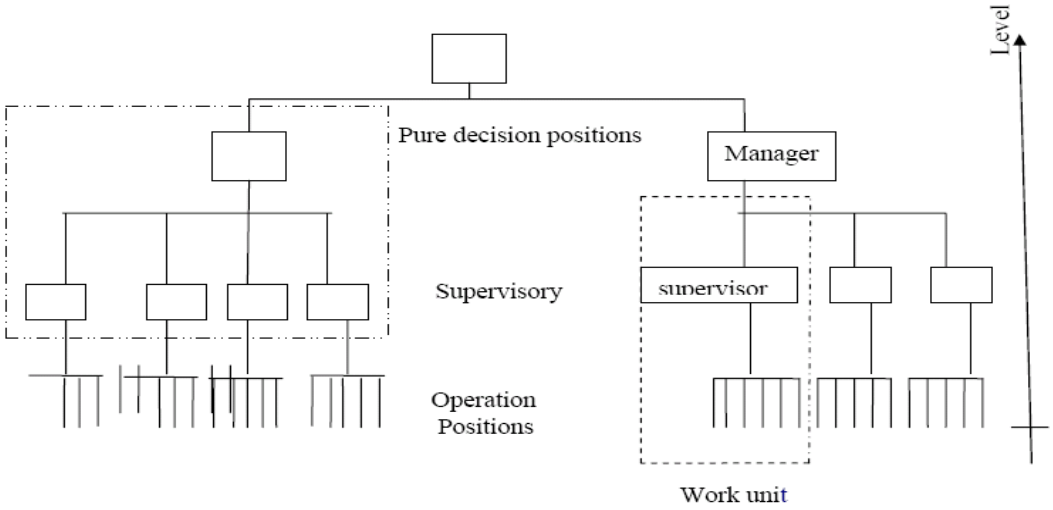

Figure 1 Organisational work units

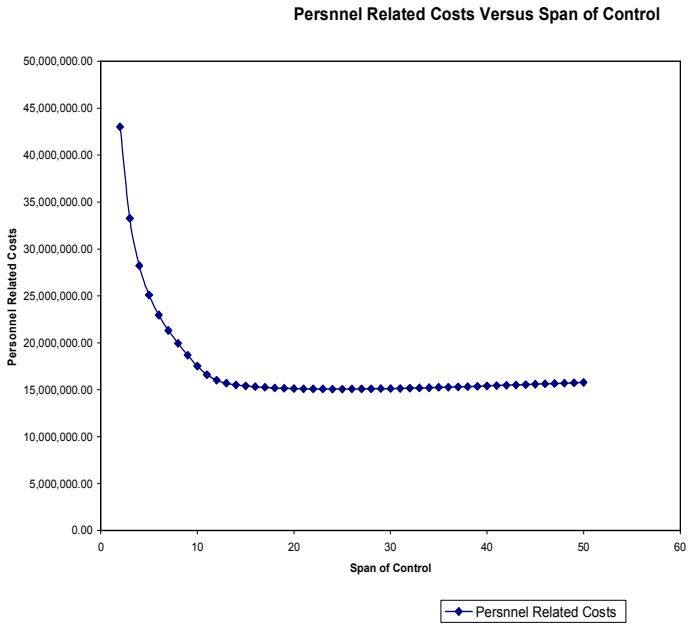

Figure 2, f_i as function of span of control K_i for λ_i=6.75. μ_i=29.5, b_0=53.1, b_1=261