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A review of the application of linear programming model in meeting organizational objective in a rapid changing business environment

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Abstract

The rapid changes characterizing the business climate in the twenty-first century creates intense difficulties for organizations in the area of resource planning and allocation. Business requires inputs in form of raw materials, men, time and other resources, in producing a given amount of outputs in achieving desired objectives. Achieving desired organizational objectives implies utilizing resources effectively using scientific approach. Hence, the study explores literatures on the application of linear programming model in achieving organizational objectives in a rapid changing business climate. The study made use of books and journals in generating relevant information. Reviews of related literature indicates that application of linear programming model has greatly contributed towards effective managerial decision-making regarding resource allocation and quantity of product(s) produced in meeting set objectives. Therefore, the need in the application of linear programming model in contending with scarce resource in pursuance of organizational objectives.

Key words: Linear programming, Optimization, Resources, Objective function, Constraints.

1. Introduction

The world is changing more rapidly than ever before, the changes characterizing today's world, presents either challenges and threat to organizations' survival or opportunities for business success. However, organizational survival as well as success in the changing business environment demands efficient and effective use of available resources in meeting objectives, as organizations are not self-sufficient, and require resources from the environment. As noted by Fligstein (2001), organization's dependence on its environment is a crucial factor in explaining the internal objectives as well as structure of organizations. Organizations' objectives (profit, growth, market share, efficiency, customers and employee satisfaction, good public image and so on), are often achieved through efficient resources usage, with respect to environmental pressures shaping management's decision. As opined by Daft cited in Ahiauzu and Asawo (2016), organizations find and obtain desired resources (man, material, machines, money), interpret and respond to environmental changes, distributes finished products, and control as well as coordinate internal activities in the face of environmental turbulence and uncertainty.

Although, resources are finite, coordination and control of organizational activities is often associated with issues of resource allocation, as individuals, teams, departments as well as divisions continually compete in the use of limited resources at organizations' disposal. Buttressing, Pfeffer and Moore (1980) states that competition over resources in the organization between departments is often inevitable due to scarcity, which elicit the use of power in promoting departments' interest. Also, products compete in making contribution to achieving organizational objectives in relation to limited inputs having varying alternatives. Similarly, organizations compete with each other in the use of scarce resources in meeting their objectives. Though, there is no doubt that organizations are faced with resource constraints, the issues confronting management is decision on how available resource can be allocated and managed in the most desirable manner to minimize cost and maximize benefit.

Notably, organizations often encounter problems regarding resources utilization while pursuing set objectives. Problems like determining how resources could be mixed and be blended, planning as well as scheduling issues. In addition, problems associated with cost distribution, issues relating to personnel allocation, plant location problems and so on, are all issues confronting organizations in relation to resources usage. Managers in confronting the issues above, arrives at making decisions regarding cost minimization and profit maximization. However, managerial decisions made regarding resources usage are often fraught with errors as a result of over reliance intuition, common sense, experience as well as executive judgement which are consider as non-scientific approach. Though, in simple organizational challenges, intuition, common sense, executive judgement as well as experience are often utilized in arriving at a desirable end, but the challenges arising from today's fast changing environment, requires organizations as well as managers' reliance on a more scientific approach using operational research.

Operational research which is an analytic approach in solving managerial problems emerge during the Second World War and was utilized by the military. Basically, the military applied this technique in proffering solutions to strategic and tactical problems. As opined by Baridam (2002), its emergence, basically offered managers of organizations a scientific basis for solving problems involving the interaction of parts or components of organization in the ultimate interest of the organization. Although, several operation research models exist (that is, network, Markovian, queuing, inventory model, simulation modelling, dynamic programming model, transportation model, assignment model and so on), however, linear programming is seen as one of the operational research approach often utilized by managers in confronting organizations' challenge regarding resource use and quantity of products produced in achieving desired objective. Wagner (2007) and Lucey (2002), extend this view by positing that linear programming is among the most commercially successful applications of operations research model.

Though, several studies (Bagshaw, 2019; Kwak & Lee, 1997) have been conducted in ascertaining the application of linear programming in managerial decision making for the purpose of achieving organizational objectives, generally, this study tends to explore literatures in examining the use of linear programming in meeting organizational objectives in a rapidly changing business climate.

2. Literature Review

2.1 Linear Programming

Linear programming model (LP) is a technique use in managing resource for optimal production. It is a mathematical (algebraic) technique in which relationships between resources and outputs in a system are described by a set of algebraic (linear) equations. Since resources are scarce, output will be constraint. In other words, output in the technique is determined by limited resources. Notably, the resource and output equations are often connected by another equation called an "objective function" which describes the desired outcome in mathematical terms (Hurley, Trafford, Dooley & Anderson, 2013). However, to obtain optimum solution in the equation, a set of mathematical procedure is observed in form of matrix inversion, which progresses following step-by-step process in achieving optimality. Bagshaw (2017) views linear programming as a linear and optimal mathematical procedure used in solving problems in determining quantities of resources that needs to be used or produced, which will either maximize benefit or minimizes cost. In other words, LP is about making maximum benefit or minimum loss out of limited resources in daily life. The model plays an important role in enhancing managerial decision and has shown to be capable of solving problem like production planning, allocation of resources, inventory control and advertisement (Sohi et al., 2013).

Mac'Odo (1997) views linear programming as a model applied in optimum allocation of limited resources to competing alternative uses, under assumptions of certainty, linearity, fixed technology, constant profit or cost per-unit and divisibility. Notably, the model plays important role in enhancing managerial decision capable of solving issues relating to product-mix, assignment of personnel and machines, investment portfolio selection, plant location, transportation schedule and so on. Managements' often aimed at making decisions in either minimizing cost or maximizing benefits, given a set of scarce resources such as manpower, money, materials, skills, time, facility and so on.

As opined by Aadharshana (2019), the process of either minimizing or maximizing is often referred to as optimization or mathematical programming. The optimization process can be utilized in solving problem using either the graphical approach or the Simplex method depending on the variables involved. Notably, the model is applied virtually in all manufacturing or productive activities as well as some service-related businesses in allocating scarce resources and determining production quantities, as it enables industries as well as businesses find optimal solutions to economic and production decisions.

Though, linear programming model is applicable across manufacturing or production as well as some service-related activities around the world, notably, Nakhanu, Toili and Nyongesa (2015) traced its earliest application to the twentieth century (1930), when Leonid Kantorovich (a Soviet mathematician) and Wasity Leontief (an American economist) first used it in manufacturing schedules and in economics. Kantorovich, developed the model in planning expenditures and returns, for the purpose of reducing cost incurred by the army (USSR) during the Second World War. Similarly, Dantzig between 1946 and 1967 developed the simplex approach used in optimal allocation of resources. The approach developed by Dantzig was used by the U.S Air Force in 1947 in planning problems. Though, linear programming was developed during the early part of the twentieth century, it is still widely in use in today's business organizations in solving multiplicity of issues relating to resources allocation.

Notably, Dwivedi (2008) averred that linear programming is highly useful in making business decision, as it aid firms in evaluating complex economic relations, which further provides an optimum solution to the problem of resource allocation. Notably, management makes decision concerning abstract economic theories in practical terms utilizing linear programming techniques, thus, as opined by Dwivedi (2008), it links the gap between abstract economic theories and decision made by management. As opined by Hillier and Lieberman, cited in Osagie and Icheme (2018), viewed linear programming problem as any problem whose mathematical model fits the very general format for the linear programming model.

Problems could be in a form of optimization as well as programming. Optimization problems are problems in which the aim, is to maximize or minimize a given quantity, often referred to as the objective function that relies on a limited number of input variables. As opined by Inyana (2006), the input variables may be independent or related through one or more constraints. On the other hand, programming problem is a problem whose aim is to determine the optimal allocation of finite resources in achieving specific objectives. However, the objective function and constraints of a linear programming model are the decision variables and parameters respectively.

Mac'Odo (1997) view the objective function as a decision on the result needed or required which may involve the maximizing of a desired outcome (contribution, utility, revenue just to mention but few) or the minimizing of negative outcomes (cost, time, distance and so on). The objective function could be stated thus: Optimize $F = a_1x_1 + a_2x_2 + a_3x_3 + \ldots. a_nx_n$. The function consists of coefficients and the decision variables. Expatiating further, a_1, a_2, a_3 …. a_n are seen as the objective function coefficients while x_1, x_2, x_3 …. x_n are said to be the decision variables. Contrarily, the constraints are seen as limitations that influence or govern the realization of the stated objectives. As opined by Mac'Odo (1997), constraints are in dual part which could either be functional or structural (that is, inequality statement or input requirements within the limits of the available resources as well as obligations) and the non-negativity or quantity constraint. It is stated thus: subject to

$$b_{11}X_1 + b_{12}X_2 + \ldots. + b_{1n}X_n \leq k_1$$

$$b_{21}X_1 + b_{22}X_2 + \ldots. + b2nXn \leq k_2$$

$$b_{m1}X_1 + b_{m2}X_2 + \ldots. + b_{mn}X_n \leq k_m$$

$$X_1, X_2, X_3 \ldots. X_n \geq 0$$

However, the constraints in minimization problem is often denoted with 'greater than or equal to' sign (≥) while maximization problems show constraints of 'less than or equal to' sign (≤). The goal is to determine the quantities of resources that needs to be produced or utilized which will maximize benefits to the organization or contrarily minimize cost incurred by organizations.

2.2 Conditions for The Use of Linear Programming Model in Problem Solving

Though linear programming is considerably applied in solving problems facing organizations in terms of quantities of resources that need to used or produce and often supports managerial decision, the model is not applicable in all conditions. However, as opined by Mac'Odo (1997), certain conditions must be met before applying LP model in solving problems. These conditions are:

1. The problem must be capable of being stated in numeric terms
2. All factors involved in the problem must have linear relationship
3. The problem must permit a choice(s) between alternative course of action
4. There must be one or more restrictions on the factors involved (restrictions on resources or characteristics)

2.3 Assumptions of Linear programming model

As stated by Martinich (1997), linear programming makes certain assumptions – Proportionality, additivity, divisibility and certainty. In addition, there are the assumptions of optimality, non-negativity.

I. The assumption of *Proportionality* implies that that the contribution of individual variables in the objective function is proportional to their value. In other words, if the value of a variable is doubled, the contribution of that variable to the objective function and each constraint in which the variable appears, doubles. The contribution per unit of the variable is constant, thus, satisfies the assumption of proportionality.

II. The assumption of *Additivity* implies that the total value of the objective function and each constraint function is obtained by adding up the individual contributions from each variable.

III. *Divisibility* – This implies that the decision variables can take on any real numerical values within a specified range. In other words, the variables are not restricted to integer value, it can be formulated to take on any real numerical value within the confines of the specified constraints.

IV. The assumption of *Certainty* implies that the parameter values in the model are known with certainty. In other words, the optimal solution achieved is ideal for the specific problem formulated. If the values of parameter are erroneous, the resulting solution becomes of little importance.

V. Non-negativity. This implies that all decision variables must take on values equal to or greater than zero. In other words, in linear programming negative values of physical quantities are an impossible situation.

Notably, Martinich (1997) states that attention be given specifically to the assumptions of proportionality and divisibility because they are most likely infringing upon by users of LP models. Also, as stated by Martinich, in a problem that requires integer solutions, the variables must be explicitly modeled.

2.3 Methods of solving a Linear Programming Model

Generally, there are two main approach or methods used in solving problems in linear programming. These include the graphical approach and the simplex approach or tableau.

2.3.1 Graphical method

The Graphical method or approach is often applied in visualizing basic concepts utilized in the linear programming problem. This approach is often use when there are only two decision variables in the LP problem, though as opined by Kannan, Dinakaran and Lavanya (2004), it can also be applied in solving for LP problems involving three decision variables but becomes rigorous when manually used. However, applying the graphical approach on problem having two decision variables involves plotting the constraints on a graph and identifying the region that satisfies all of the constraints. In other words, the areas in the graph that accommodates all the constraints is seen as feasible region.

This region is also known as the feasible solution space. After plotting the constraints and identifying the feasible region, the objective function is then plotted and used to identify the optimal point in the feasible solution space. The point is then explained directly from the graph or determined by substituting all the coordinates of the corners into the objective functions as these joints form the feasible solution region of the linear programming problem. However, the highest of the values in the optimum solution, indicates maximization problem. Contrarily, the smallest of the values in the optimum solution of the linear programming problems, indicate a minimization problem. Since it becomes difficult to solve linear programming problem with more than two variables graphically, the simplex method is then utilized.

2.3.2 Simplex method

The Simplex method is often applied when solving for decision variables that ranges from three and above. The simplex approach is an iterative procedure that progressively approaches and ultimately arrived at optimality to linear programming problem. Mac'Odo (1997) views it as step-by-step arithmetic process of solving LP problems in which optimality is obtained after moving progressively from one feasible solution to another. The simplex tableau contains four columns – basic variable, decision variable, slack variable and the solution quantity column respectively. From the tableau, the pivot column, pivot row and the pivot element is being identified. However, there are steps involved in using the simplex method. These include:

a) Formulating the problem by identifying the objective function and the constraints
b) Adding slacks to each of the constraints
c) Set up an initial Simplex tableau.
d) Identify the Pivot column, row and pivot element
e) Development of main row and balance for a new table.
f) Iterative process of the above steps by using matrix operation, ensuring that the elements in the pivot above and below the pivot element are zero. The solution is optimal when the elements in the last row (the objective function row) are either zero or negative (-).

Table 1: Formulation of the initial simplex tableau.

Basic variable	Decision variable	Slack variable	Solution quantity
	$X_1\ X_2\ X_3 \ldots\ldots X_n$	$S_1\ S_2 \ldots\ldots S_M$	
S_1	$b_{11}\ b_{12}\ b_{13} \ldots b_{1n}$	$1\quad 0 \ldots\ldots 0$	K_1
S_2	$b_{12}\ b_{22}\ b_{23} \ldots b_{2n}$	$0\quad 1 \ldots\ldots 0$	K_2
:	: : : :	: : :	:
S_M	$b_{m1}\ b_{m2}\ b_{m3} \ldots b_{mn}$	$0\quad 0\quad 1$	K_m
Z	$a_1\ a_2\ a_3 \ldots\ldots a_n$	$0\quad 0 \ldots\ldots 0$	0

Source: Mac'Odo (1997).

2.4 Application of Linear Programming model in Real Life Problems and Firms' Objectives

Generally, linear programming model is applied in proffering solutions to many real life problems. As averred by Miller (2007), the reasons for its great versatility is as a result of the ease at which constraints can be included in the programming model. However, its wide application has been shown in numerous areas of studies in human endeavor. For instance, Hurley et al. (2013), conduct a study in ascertaining the usefulness and effectiveness of linear programming models as farm management tools in New Zealand. Two approaches (case study and expert evaluation, specifically with Grazing System Ltd model) were utilized in assisting consultants and their clients to identify feasible and profitable changes to their farming systems. The study inferred that LP analysis generates information about the optimum use of resources and the opportunity cost of using those resources. The information provides the opportunity to redesign the farm system and introduce more profitable strategies.

Similarly, Kareem and Aderoba (2008) conducted a study in examining the effectiveness of adopting a linear programming model in maintenance and manpower planning in cocoa processing industry in Akure, Ondo State of Nigeria. Findings from the study indicates that only four maintenance crew out of the 19 employees are needed in that section to effectively carry out maintenance jobs in the industry. Study conducted by Susilawati, Litaay, and Parsaulian (2002) examined the use of linear programming in dormitory development at Petra Christian University in calculating the number of rooms and area of each facility with consideration on the limited space of 4,994.83 square meters and a maximum cash flow of Rp 392,952.00 which is discounted by 17% per annum for seven years. Special computer software known as SOLVER which is capable of solving mixed integer and LP model was utilized in calculating the number and area of facilities - bathrooms, dining rooms, common rooms, cafeterias, bookshops, mini- markets, phone booths, sports facilities and parking spaces. Finding indicates that apart from garden, all supporting facilities need to be supplied.

Fagoyinbo, Akinbo, and Ajibode (2013) conducted a study on maximizing profit in manufacturing industries using linear programming techniques using data from GEEPEE Nigeria limited. The study employed the concept of revised simplex method (an aspect of linear programming) to solving industrial problem. The company specializes in producing different types tanks. Four different types of tank were sampled for the study, which are the Combo, Atlas, Rambo and Jumbo tanks of various sizes. Finding indicates that, given the amount of materials available, polyethylene (Rubber) and Oxy-acetylene (Gas) used in the production of the different sizes of the product, Combo tanks assumed more objective value contribution and gave maximum profit at a given level of production capacity.

Notably, Issam (2006), applied Linear programming approach to optimizing strategic investment in examining the issues of workforce training and allocation on construction projects. The objective was to reduce project costs and improve schedule performance. The input data to the proposes model consists of certain available labor pool, cost figures for training workers in different skills, the cost of hiring workers, hourly labor wages, and estimates of affinities between the different considered skills. Application of the model, minimizes the labor costs while satisfying project labor demands.

Akpan and Iwok (2016) applied Simplex method in allocating raw materials to competing variables (big loaf, giant loaf and small loaf) in bakery for the purpose of maximizing profit. Results of the analysis indicates that 962 units of small loaf, 38 units of big loaf and 0 unit of giant loaf should be produced in achieving a profit of ₦20385. From the analysis, it was revealed that small loaf contributes most in achieving desired profit, followed by big loaf. Thus, production and sales of smaller loafs and big loafs is required in maximizing profit.

3. Conclusion

It is evident from literatures reviewed that linear programming model has contributed toward managerial decision making in handling scarce resources at organizations' disposal and has help firms determine quantity of product required in achieving predetermined set of objectives. Though, managers and business owners, to some extent rely on intuition, experience as well as executive judgement in making decision, the changes charactering today's business climate requires a more scientific and objective approach in meeting organizational goals. Thus, the need in the application of linear programming model in organizations' operations for the purpose of minimizing cost as well as profit (benefit) maximization.

References

Aadharshana, V. M. (2019). Resource optimization in construction. *IJESC, 9*(11), 24019-24022. Retrieved from http://ijesc.org/

Akpan, N. P., & Iwok, I. A. (2016). Application of linear programming for optimal use of raw materials in bakery. *International Journal of Mathematics and Statistics Invention (IJMSI), 4*(8), 51-57.

Baridam, D. M. (2002). Management and organization theory. Port Harcourt: Sherbrooke Associates.

Bagshaw, K. B. (2017). *Decision analysis for managers: Quantitative approach.* Nigeria: Luckozim Nigeria Ltd.

Dwivedi, D. (2008). *Managerial economics.* New York: McGraw-Hall Inc. VIKAS Publishing House PVT Limited, New Delhi Outline Series.

Fagoyinbo, I.S., Akinbo, R.Y., & Ajibode, I.A. (2013). *Maximization of profit in manufacturing industries using linear programming techniques: GEEPEE Nigeria Limited*. Proceedings of the 1st International Technology, Education and Environment Conference at African Society for Scientific Research (ASSR).

Hurley, E., Trafford, G., Dooley, E., & Anderson, W. (2013). *The usefulness and efficacy of linear programming models as farm management tools*. New Zealand: OneFarm, Center of Excellence in Farm Business Management.

Issam, M. S. (2006). Linear programming approach to optimize strategic investment in the construction workforce. *Journal of Construction Engineering and Management © ASCE, 132*(11), 1158-1166.

Kannan, T. R., Dinakaran, G., & Lavanya, N. J. (2004). *A graphical approach for solving three-variable linear programming problems.* Paper presented on Recent Developments in Materials Processing (RDMP-04) at Bharathiyar College of Engineering and Technology, Karaikal, India.

Mac'Odo, D. S. (1997). *Quantitative and statistical analysis for business decisions*. Port Harcourt: Linnet Paul Publications.

Martinich, J. S. (1997). *Production and operations management: An applied modern approach.* New York: Wiley.

Nakhanu, S, B., Toili, W.W., & Nyongesa, K. (2015). Application of linear programming knowledge and skills to real life contexts by secondary school students in Kenya. *Journal of Scientific Research and Reports, 8*(1), 1-7.

Osagie, G. N., & Icheme, M. O. (2018). Optimization of resources with the aid of linear programming model in Steve Shoe Production Centre, Enugu, Nigeria. *International Journal of Research-Granthaalayah, 6*(9), 123-136.

Pfeffer, J., & Moore, W. L. (1980). Power in university budgeting: A replication and extension. *Administrative Science Quarterly, 24,* 637-653.

Sohi, L. M., Bazardch, S.M., Khoshsneed, S., Mahmoodi, N., Rasbti-Abadi, F. Q. & Mohammad, M. O. (2013). Linear programming and optimizing the resources. *Inter-disciplinary Journal of Contemporary Research in Business, 4*(11), 701-705

Susilawati, C., Litaay, D. L., & Parsaulian, A. (2002). Application of linear programming for dormitory development plan at Petra Christian University. *DIMENSI TEKNIK SIPIL, 3*(2), 59-63

Wagner, H. (2007). *Principles of operations research with application to managerial decision*. New Delhi: Prince-Hall of India Private Limited.

Fligstein, N. (2001). *Organizations: Theoretical debates and the scope of organizational theory. Handbook of Sociology.* London: Sage Press.

Ahiauzu, I. A., & Asawo, S. P. (2016). *Advanced social research methods. CIMRAT lecture manual.* Port Harcourt, Nigeria: CIMRAT Publication.

Lucey, T. (1982). *Quantitative techniques: An instructional manual*. London: ELBS/Pitman Publication.

Bagshaw, K. B. (2019). A review of quantitative analysis (QA) in production planning decision, using the linear programming model. *American Journal of Operation Research, 9*(6), 255-269.

Kwak, N.K., & Lee, C. (1997). A linear goal programming model for human resource allocation in health-care organization. *Journal of Medical System, 21*(3), 129-140.

Kareem, B., & Aderoba, A. A. (2008). Linear programming based effective maintenance and manpower planning strategy: A case study. *International Journal of the Computer, the Internet and Management, 16*(2), 26-34.