

QUANTITATIVE TECHNIQUES IN MANAGEMENT SCIENCES (A focus on LP)

by

Prof. Dr. A. Z. Memon
Pak-AIMS, Lahore

1. INTRODUCTION

The scientific use of quantitative tools was started by Fredric W Taylor in 1900 but their modern usage is generally known to have got impetus during world war II when teams consisting of people from allied powers with diverse specialities were set up to solve strategic and tactical problems confronting military.

Over the last few decades the awareness about the use of these tools in management has been rapidly growing. Whether it is an organization managing administrative activities, or it is an industry manufacturing products, or even in the services sector, quantitative tools are now regarded imperative for the purpose of seeking in-depth knowledge of the situation involved. This information is not merely interesting to satisfy the curiosity of any inquisitive researcher, it is useful to a planner, a decision maker, or the one regulating and improving the management control. With the growing awareness of the importance of business administration, interest in applications of quantitative tools has also been trending up in dealing with the problems of management. Numerous applications of these tools are emerging. Both mathematical and statistical concepts now benefit most of the management sciences in widening their scope and enhancing their effectiveness.

The problems of management, finance and marketing that can be quantitatively expressed, modeled or visualized, may be best tackled in situations for which relevant tools are available and applied. Information arising from their use simplifies the managerial decision making process, facilitating an informed choice of objective decision alternatives. With the advent of the TQM concept, some of these tools have gained much popularity with the consequence that in Pakistan now every quality business school has either introduced or aspires to introduce these tools in their education programs. Various banks and industries are also showing their interest in promoting the quantitative competence of their staff through training.

The purpose of this paper is to throw light on the importance of quantitative tools in management sciences. Whereas I would be briefly referring to other tools, this paper will mainly review and discuss some applications of linear programming of possible interest to management.

2. WHY QUANTITATIVE TOOLS?

Operational research, probability theory and statistics provide a number of quantitative tools that are valuable to management sciences.

Quantitative tools are now used to assist the management in its planning, scheduling and controlling activities. It is hard to imagine to carry out these functions without reference to numbers. Concepts as simple as percentages, ratios, totals, average even if not computed, appear in a manager's language quite often. He just cannot avoid it. As a matter of fact such elementary concepts have remained in use for long both in business and industry. Apart from industrial management, other areas of business also benefit from these tools. Most executives have a big, hairy and ambitious goals, and in order to transform their organizations' respective wildest dreams into reality have to bank upon information as reliable as possible because they have to develop complicated effective programs, formalize rules and procedures. For instance, a marketing executive may hypothesize that higher levels of performative action will increase a consumer's support for the organization, and based on test of this hypothesis in the market he is to take a measure to promote his goals. This simple hypothesis demands setting up of definitions of variables to be introduced before planning the inquiry. Recently, a marketing manager was interested in conceptualizing the effects of joint advertising (with two brands advertisement) on consumers in conditions of high involvement. The brand awareness, brand accessibility and brand attitudes were deemed by him as relevant variables mainly to know when should brand managers seek complementary partners, and when non non-complementary partners; and to determine the effective advertising strategies in these situations.

Marketing activities often depend upon marketing surveys as a means to improvement of product through customer's feedback. Experimental designs may be employed too for testing various hypotheses. Product designing may be done through these devices. The obvious implication being that it requires statistical knowledge for the management of these inquiries, elementary or advance, ranging from the technicalities of questionnaire making, and then moving from one statistical phase to the other till the valid conclusions are based on statistical inference. The more focussed, objective, and reliable the information is the greater the service it renders to its intelligent user.

Elementary tools in statistics have their value, but the availability of multivariate statistical tools may provide further useful information to management. For example, in order to gauge respondents' attitudes towards inflation if a marketing survey includes a large number of statements each carrying an assign-able score (strongly agree, undecided, disagree, strongly disagree) it will be useful to know the statements that appear more similar. It will be further useful to combine them in groups and evolve meaningful factors to understand their significance. Obviously with this information, marketing plans can be developed accordingly.

Linear programming is used by management involved in production, financial planning, investment, etc. Transportation problems arise in transportation of a product from supply stations to demand locations. Assignment problems are caused when the members of a set are assigned to the members of another set in an economic manner, and as such it finds applications in marketing, consultancy organizations, etc. Goal programming is now becoming popular in dealing with two or more objectives as contrary to one in linear programming, and is so useful various management areas. PERT / CPM is often used in construction of plants, complexes and highways for coordinating and scheduling various activities; its applications also occur in the development of new products and processes. Inventory models are applied for the management of inventories in production and other situations to meet the clients' demand for a product. Waiting line models are used as economic strategies by the management (supermarkets, banks, restaurants etc) for operation of waiting lines. Markov process facilitates the prediction of probabilities of switchover from one condition to the other. Marketing specialists apply this tool in forecasting marketing shares. Each tool has its own domain of applications, some being more applied to one area than to other areas of management.

For selection of optimal decision alternatives, probabilistic approaches are employed. Decision analysis is based on the use of probability theory. Expected criteria are commonly used when information regarding the unpredictable events is known with corresponding probabilities. This area is quite often used in investment planning, strategy selection, and production decision making. The use of posterior probabilities enhances the value of decision analysis.

Elementary statistical concepts have been in use for long. Forecasting tools are also employed in sophisticated inquires. In addition to univariate methods including exponential smoothing, Holt-Winters and Fourier analysis, the use of ARIMA models is also made by the analysts and managers engaged in business activities. The design of experiment has frequent applications in marketing for the development of new products. During last few years there is an increasing trend for using multivariate tools for data analysis and forecasting. Factor analysis, cluster analysis and discriminate analysis are gaining popularity

in management due to their usefulness. Mostly these areas find interesting applications in marketing.

3. APPLICATIONS OF LINEAR PROGRAMMING

Linear programming, whether relaxed or non-relaxed, is mainly used in production management, but this area has other applications as well. Below, an attempt is made to pick up its popular applications in management.

Management is a vast term. It depends on as to what type of situation a manager is confronting and where linear programming is applicable. A production manager grapples with his own economic problems for production of quality products. A financial manager is interested in investments, and comes across various financial planning problems. A marketing manager may wish to minimize the cost in approaching a target population through different media. A blending manager may be interested in mixing various materials at the minimum cost without sacrificing the specifications. A transporter may wish to minimize the cost of transportation from one set of location to the other set of locations. A pollution control manager in a chemical industry may not wish to violate the government regulations when deciding about the production levels of a product for which the manufacturing process discharges pollution causing material. A diet may have to be formulated following minimum requirements of carbohydrate, protein etc. All these management problems could be translated, investigated and solved by means of the context of linear programming technique.

Linear programming has been successfully applied both in services and industrial sectors. We consider below some applications of linear programming in rather a more detailed manner.

3.1 Production Planning

A production manager often applies linear programming in determining production levels in industry. Problems that call for the number of units of two or more products to be manufactured subject to resource restrictions may be tackled by setting up proper linear profit and cost functions and a system of constraints. Effective planning calls for additional information prior to implementing the optimal solutions. The reference is to sensitivity analysis of linear programming. It is highly useful to investigate the effects of changes in resource coefficients even before implementing a production strategy. Sensitivity analysis of linear programming models provides valuable information for making decisions regarding the choice of production strategies.

3.1.1 Production scheduling

The problem is no longer simple when the demand for the products ranges over more than one period, the required inventory levels are indicated, the machine labour and storage capacities are stated. The multi-period planning is further complicated if the cost of increase or decrease in production level is not constant. The objective is to evolve the minimum cost production schedule, that is, to determine the production levels to meet the customer's demand for each period at minimum production, inventory, change-in-production level cost. Separate components of total cost based on the optimal production schedule is information providing a food for thought in case the production management is interested in taking cost reduction measures. The knowledge of resource (machine), labour and storage usage coming through the linear programming model is vital for running production affairs efficiently. For such a problem, more specifically if we have six structural variables, three periods, inventory level for each product under each period, increase/decrease-in-production level for each product we have to consider eighteen variables in formulating the objective function and constraints in developing an optimal production schedule. Thus the complexity of a production problem obviously grows with the number of variables involved for this kind of decision making. It is claimed by production managers that production scheduling may involve at times hundreds of variables and a large number of constraints. Whereas it is cumbersome to evolve such a complicated linear programming model, obviously the benefits of this effort are also there.

3.1.2. Blending problems

These problems are common in chemical industries. A feed for animals may be made up at the minimum cost by mixing different kinds of grains to achieve certain minimum nutritional requirements. Gasolines of various grades may be obtained by blending components of other gasolines. Shampoos are produced by mixing various materials to achieve the final product with the specified characteristics. Blending problems also occur in plastic and other industries. A blending manager combines two or more components in desired proportion to produce one or more product meeting the given specifications. Such blending mainly aims at minimum cost production so that the objective function is based on cost of producing new products. Availability of material restrictions are there, and so the demand for the blended products and their specifications. These data result in constraints for the linear programming model to answer the question 'How much to mix one material with the other to produce the desired result at the minimum production cost?'

3.2. Financial Planning

Linear programming has been used in investment planning, capital budgeting, asset allocations, purchase decisions and in various other financial situations. Financial managers have to identify the utility to be optimized, express the financial policies algebraically, quantify other financial constraints and consider the linear programming approach for its application. Where this tool is applicable, the use of sensitivity analysis helps the management to modify their financial planning for its improvement. We discuss briefly below the financial situations where the quantitative tool under consideration is often made by the financial managers.

3.2.1. Portfolio Selection

Given a number of permissible investment opportunities with their return rates, funds availability restriction, or some financial policies regarding the consideration of these investments, the important question is how should the funds be optimally invested. Since larger return yielding investments are often risky, the need for this consideration is also included in the overall mathematical model. That is, an optimal return yielding basket of investments with how much to invest in an opportunity is required to be determined. Any other mixture of investments cannot yield a better average return rate. The problem assumes a monumental difficulty when the financial parameters and restrictions on the solution increase. If the LP model can be successfully applied, it is interesting to explore the effects of certain modifications in financial policies through the use of range of feasibility, dual prices. Such approach of a manager could be useful and may even question him on the wisdom of sticking to certain policies, or motivate him to consider certain changes in the policies.

3.2.2. Capital Budgeting

This aspect of financial planning is common to those managers where an investment opportunity is available and they have to decide whether or not to select this project. A number of projects with their present or future values are available for consideration, the cash flow requirements for their completion each year are known, annual availability of capital is indicated in advance for their completion and there may be some other conditions regarding the acceptance of these projects. The problem of selection of the most profitable projects calls for setting up of numerous permutations and combinations and even if the optimal solution is arrived, it may be difficult to verify this claim. And yet, the questions regarding the sensitivity analysis of the whole financial situation remain unanswered. The linear programming with added constraints on the use of structural variables to be 0,1 simplifies the conceptual understanding of the whole capital budgeting problem.

3.2.3. Purchasing Decisions

As stated above there arise purchasing situations where the problem is to decide as to how many units of various facilities to be ordered for which purpose limited funds are available. The facilities are required to satisfy the purchaser's demand. For example, if there are three facilities, the purchasing cost and the operating cost of a facility is known, each facility has a specified capacity of some service to render, funds are limited, the demand for the total service is indicated quantitatively, the purchasing policy regarding these facilities is given, the problem of deciding the number of units of these facilities to be purchased at minimum cost can be well taken care of by the application of linear programming.

Whether to manufacture or not? An industrialist when manufacturing products may not manufacture all the components to comply with the demand for the products in the market. Even when he has the ability it may not be not economical for him to manufacture all the components. Whether to manufacture these components or purchase some of them for the production of products is an important decision for him. The use of linear programming is made in these situations as well.

3.3. Marketing Applications

The use of linear programming provides useful guidance in deciding which marketing strategies to follow for effective advertisement of a product, product designing, and even selection of places for conducting marketing surveys.

3.3.1. Advertisement

Advertisement which is vital for the promotion of a product in the market calls for this campaign through the electronic and printed media in addition to other measures. The interest of an advertisement manager lies in reaching through these media a population as large as possible and plan the media selection. Such a plan has not to lose the sight of the media availability restrictions, the budget specified, the cost of these media, their accessibility to the target population, their appeal and exposure quality to the people. Some marketing policies regarding the use of these media may also be added by the management. The solution is to be an optimal use of funds. The sensitivity analysis of the LP model if used, throws further light on the policies and their relationships with the parameters of interest to the manager.

3.3.2. Product Designing

For product designing in view of the needs of a target population, it is important to reach that population for its suggestions and feedback. A poorly planned survey can be misleading, confusing and frustrating. The marketing managers have used the linear programming tool as a precautionary measure

against these risks. Before they run a survey they to pre-specify their demographic requirements of the people to be contacted. So that there are their expectations with regard to the characteristics of target population, budget allocations, and probably some other practical considerations vital to the survey.

3.4. Staff Scheduling

In large companies it is the intention of the management to minimize man hours through proper staff scheduling. Applications of linear programming also appear in this area for economic purposes. The management is to hire the staff on permanent and temporary basis to meet its job opportunities during different time slots over a day's activity. The objective may be to get the minimum number of employees subject to the pre-specified demand. Minimum wage schedule may be the other objective of the management.

A labour manager often comes across problems where some departments of his industry produce the same products but for whose production the labour requirements/unit differ among departments. When the labour hours available for each department is known, his interest lies in using a product mix-linear program for making the maximum profit. If some additional labour hours also become available for some or more departments, the decision calls for efficient department staffing schedule.

3.3. Network Flow Problems

Networks consists of nodes and arcs that join them. Transportation and assignment problems are members of a category of linear programming tools, called network flow problems.

3.5.1. Transportation

Though the problem of deciding as to how much to transport material from given supply sources to pre-specified demand locations is a separate quantitative tool, the application of linear programming model can also be made in achieving a transportation schedule at the minimum transportation cost. Constraints arise due to limited supply capacities at each source and the demand at each location. If a route is closed, or not desirable for operation, or certain routes must be followed, the model simply is augmented with these mathematically expressed constraints.

Large transport companies use linear programming to minimize their transportation expenses to ship the material from several sources to numerous locations within a country, even from one country to another. Mervine Lawrence in her paper "Earthmoving, On construction Projects" - Interfaces Vol 14 No. 2 pp84 - 86 illustrates a transportation problem where a large company has to move

the 1.8 cubic meters of sand at 26 sites to 35 fill stations. In addition to cost factor there was a time factor to be included in the model.

3.5.2. Assignments

The problem of assigning individuals to individuals of other set occurs in various management situations. Information on cost (profit) is given for assigning a member of the first set to the member of other set. The aim is to determine an optimal assignment pattern.

For example, the leaders in a consultancy organization are assigned to clients, say 1-1 basis to do their jobs and the objective is to select an assignment structure, optimal in terms of minimum time to be spent by the organization. Sales representatives may be assigned to territories to achieve maximum benefit through the use of linear programming model. Machines producing products may be assigned products in a manner that will yield maximum profit.

4. Concluding remarks

The above material briefly reviews, discusses and highlights the role of the linear programming model in management sciences giving an idea to the readers as to how economically, precisely and objectively certain problems of management can be solved. With time the quantitative tools are entering the domain of management sciences and widening the scope of these disciplines. When these tools are employed for interaction with management sciences, invaluable insights are revealed, elevating some new perceptions, contributing knowledge, and providing wonderful food for reasearch.

