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Utilization of Operations Research in Agriculture Sector

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Abstract—*Operations Research is the branch of mathematics in which advanced logical theories and models are studied to enhance in better decision making and optimum utilization of resources. Applications of operations research techniques in the field of agriculture sectors have been the theme of this paper. They are applied to various aspects of agriculture like day – to - day decisions of farmers like choosing the right type of grain, farm planning, cost minimization and profit maximization on an individual farm and also production. This research paper describes various operations research theories and models applied to agriculture, demonstrating them with cases and problems.*

We would focus on two major techniques of operations research which are used in agriculture area frequently these days.

Linear Programming Model, Network Analysis

Keywords: *Linear Programming Model, Network Analysis, Agriculture, Operations Research, Profit, Optimal.*

INTRODUCTION

As we know that agriculture has been a low benefit able and high risk occupation. In present scenario in the Indian agriculture sector, the sector suffers loses, improper resource management and lack of modernization.

In this research paper, our main aim is to throw light on modernizing the approach towards the agricultural sector via the knowledge of Operations Research.

Through secondary research it came to light that there is a need to focus on agricultural management through various techniques such as linear programming, network analysis etc, this would induce a shift from the traditional approach and ensure optimal use of resources and maximum profits for the labour involved.

For the purpose of the study, we have taken two major techniques that are both easy to comprehend and implement. The study involves individually focusing on every technique, its relevance, practicality and its mathematical derivation. Every technique will also talk about various areas of farming enterprises where that technique can be utilized with a significant advantage.

The techniques which are being discussed are

I. Linear programming model
II. Network Analysis model

LINEAR PROGRAMMING MODEL AND IT'S APPLICATION IN THE AGRICULTURAL SECTOR

Agriculture is the backbone of any country, keeping in line with this many European countries, Japan and limited parts of the USA are highly invested in using the linear programming model approach also called "programme planning" in order to optimize their produce and for an optimal running of their resources.

CONCEPT USED FOR A LINEAR PROGRAMMING MODEL

1. Finding values of the objective function at the extreme points
   I. The problem that arises while solving a linear programming problem is to find an efficient set of extreme points of a convex polyhedral set determined by the objective function.
   II. In a linear programming problem every extreme point is a basic feasible solution under the set of constraints,
   III. similarly every basic feasible solution is also an extreme point of the set of feasible solutions
2. Choosing the optimum value

Furthermore the maximum or minimum optimum value of C^t, as x varies over j, will be one or more of the extreme points of n.

Maximize $Z = c_1 x_1 + c_2 x_2 + \ldots\ldots\ldots\ldots\ldots\ldots + c_n x_n$

Subject to:

$a_{11} x_1 + a_{12} x_2 \ldots\ldots + a_{1n} x_n \leq b_1$

$a_{22} x_2 + a_{22} x_2 \ldots\ldots + a_{2n} x_n \leq b_2$

$a_{m1} x_1 + a_{m2} x_2 \ldots\ldots + a_{mn} x_n \leq b_m$

$x_j \geq 0$, j=1,2,3………n

Can be also written as

Max $Z = C^t X$

Subject to

$AX \leq b$

$X \geq 0$

X represents the vector of variables (to be determined) while C and b are vectors of known matrix of coefficient. The expression to be maximized is called the objective function (C^t in this case). The equation $AX \leq b$ is the constraint which specifies a convex polyhedral set over which the objective function is to be optimized. The coefficients (c_1 ,c_2, c_3 ... c_n) are the unit returns for the coming from each production process (x_1 ,x_2....x_n).

MATHEMATICAL FORMULATION

To formulate the problem mathematically: the following notations are used

Z = The objective function to be maximize

X_j= Input Variables

c_i = Cost coefficients of the objective function Z

b_i= Maximum limit of the constraints

a_{ij}= Coefficients of the functional constraint equations

Maximize $Z = \sum_{i=1}^{n} c_I x_j$

Subject to constraints

$\sum_{j=1}^{n} A_{ij} x_j \leq b_i$

$x_j \geq 0$

$A_{ij} = [\, a_{ij} \,]_{mxn}$

$x_j = [\, x_{ij} \,]_{mxn}$

$b_i = [\, b_{ij} \,]_{nx1}$

$\sum_{i=1}^{n} c_i x_j$

$x_{ij}, c_i, b_i \in R$

APPLICATION OF LINEAR PROGRAMMING IN AGRICULTURAL SECTOR

Linear programming finds its application in a vast array of fields. Since its inception, operations research is being utilized for

1. The problem of minimization of costs of feed: The optimal function becomes the total cost incurred while the prices and quantity become the constraints.
2. On the Choice of a Crop Rotation Plan: The model can be used to pick an optimal crop rotation pattern to gain maximum profit while the cost incurred at producing them becomes the constraints.
3. Field of feed-mixing for nutritional requirements: The model uses various combinations of feed in order to obtain an optimal feed combination keeping in mind the nutritional requirements for the animals.

QUANTITATIVE MEASURES OF AGRICULTURAL SECTOR IN LINEAR PROGRAMMING PROBLEM

- Optimal crop pattern and production of food crops with maximum profit is important information for agricultural planning using optimization methods. Crop yield, man power, production cost and physical soil type are required to build the method.
- This technique can be highly useful for individual farmers if the quantitative measure, as mentioned above, of various alternative methods and resource use can be provided. Moreover, if implemented properly the benefits obtained from the implementation exceeds the cost incurred by the farmer for implementing the said technique.
- On a large scale or a macro level, this technique helps the farming population in agricultural management and spatial analysis.
- Spatial linear programming analysis can help studies related to inter regional production and major crop adjustments. Transportation models are the simplest of linear programming models applied in agriculture.

SIMPLEX METHOD

The simplex method is another technique of finding out the corner positions (extreme values). In this method, the slack variables, introduced to convert the inequalities to equalities and the coefficients of these slack variables in c vector are zero.

Maximize $Z = \sum_{j=1}^{n} c_i x_j$

Subject to

$\sum_{j=1}^{n} A_{ij} x_j + x_{n+i} = b_i$

$x_j \geq 0$

LINEAR FRACTIONAL PROGRAMMING

The problem is to optimize the objective function which is the ratio of two linear functions of the decision variable with the constraints being linear. The linear fractional function programming technique is applied wherever the objective function is defined as a ratio.

MATHEMATICAL FORMULATION

Maximize $f(x) = \frac{h' . X + \alpha}{g' . X + \beta}$

Subject to $A . X \leq a,$

$B . X \geq b,$

$E . X = e,$

and $X \geq 0,$

where the matrices A, B, E, as well as the vectors h, g, a, b and e, have appropriate dimensions while α and β are scalars. Without loss of generality we assume that a, h and e are non-negative. Various authors e.g. Charnes and Cooper, Isbell and Marlow, Mortos, Wolf and Anstreicher have evolved algorithms for solving LFP problems. All these algorithms start with the following three assumptions:

1. The denominator of f(x) does not vanish in the feasible region:
2. The denominator of f(x) is positive;
3. The feasible region is bounded.

APPLICATION OF LINEAR FRACTIONAL PROGRAMMING IN THE AGRICULTURAL SECTOR

- Maximizing various macroeconomic determinants such as rate of growth, per capita income etc with respect to the agricultural sector is one of the objectives of economic planning. These can be depicted as ratio concepts therefore linear fractional programming serves as an essential technique to maximize such determinants.
- Furthermore on a microeconomic level also this technique can be used for individual farmers as well using various measures of profits such as net returns, family labour income, income from farm business etc using an appropriate denominator For e.g. maximizing returns per hour of labour used on the farm, maximizing profits per rupee invested etc.

III. NETWORK ANALYSIS AND ITS' APPLICATION IN THE AGRICULTURAL SECTOR

The past years have witnessed a growth and improvement of the old and emergence of the new management planning and control tools being grouped under the head of 'network* or 'flow' plans, these were independently and simultaneously developed by the military and the industry and include PERT (Program Evaluation and Review Technique), CPM (Critical Path Method), etc. The 'network' consists of a series of related events and activities and their relationship is sequential. PERT was advanced by the U.S. Navy in connection with the Ballistic Missile Program whereas CPM was developed under the patronages of the industry in the United States of America.

Defining some terms that would be frequently encountered in connection with the 'network analysis' and will assist in understanding the tools are,

Activity: It is a time-consuming constituent and occurs between two events. In simple words, an activity depicts a 'thing' that is required to be done in order to go from one event to another. The activities are denoted in a network diagram via an arrow.

Events; they are the goals or milestones that need to be done. Any two events are connected by an activity that is an arrow; they are at the starting as well as at the end of it. In a network diagram their representation is through a node or a box.

Positive Slack: It is the cap of additional time available to the firm to perform activities in a given slack path and still allows the activity to be completed within the needed time.

Negative Slack: It is the amount of time, which is not available to the firm to conduct the series of activities in a given slack path and still allow the activity to be completed within the required time.

Critical Path: Critical Path is a path having the largest amount of negative or the smallest number of positive slack.

A network consists of a sequence of related activities and events. It is a flow plan or a pictorial representation of the activities with the events that lead to the attainment of the ultimate objective and also illustrates a plan with activities and events arranged in an order of precedence. Hence with the assistance of this simple tool, the management can attain a position to plan the best possible use of resources in a manner that the milestone is achieved within the required time and given costs.

Network Analysis has been broadly used in industries for planning, scheduling and estimation of the projects. A very few applications of this analysis have been put to use in agriculture. The most elaborate application of this has been done to solve the problem of labor. Critical path algorithm was used to find out the solution to the problem of selecting a machine for corn production and also in making the contrasts in the costs of different systems of production.

Now we present an example

An Indian farmer intends to follow a one-year rotation of green manure taking the crop as wheat. Leguminous crops like sun hemp seeds are sown in the 'Kharif season and ploughed in the soil at their applicable period of growth to aid as a green manure for the subsequent wheat crop. Typically, this is to be functioned from the middle of August to the first week of September because at this point of time the manure plants are moist to quickly release nutrients in the soil and there is adequate time for soil to engage the nutrients. The farmer can cultivate in the manure either with the assistance of a tractor if he owns one or can rent it and even bullocks can be used.

Ploughing in by the tractor will take nearing two days, whereas ploughing in by the bullocks is bound to take six days. Considering the heavy demand for the tractor, its availability is questionable and it might take up to 8 days to be available. His land properly cannot be prepared and get on with the succeeding activities till he has ploughed the green manure in. Furthermore, sowing can be done earliest only after six weeks of ploughing in the green manure and at the latest by the last week of October. He can sow with the bullock-drawn seed penetrate or in rows behind the plough, but again if he does not own the seed drill but has to take it on rent, which might take up to a good number of three days again.

The events, activities and the expected time required by each are stated here. They are:

A1 = Obtaining the tractor

A2 = Ploughing in the green manure through the means of bullocks

A3 = ploughing in the green manure crop via a tractor

A4 = Arrangement of the field for sowing by bullocks

A5 = Obtaining the drill for the process of sowing

A6 = Scattering/ Sowing behind the plough

A7 = Scattering/ Sowing via the seed drill

The corresponding events are:

E1 = Initiation/ Start (August 21)

E2 = Tractor obtained

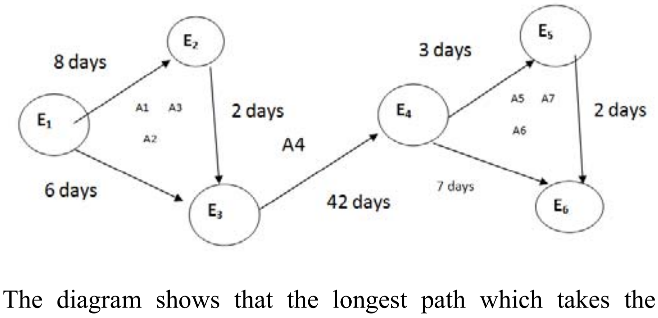
E3 = Field being green manured

E4 = Field prepared and made ready for sowing

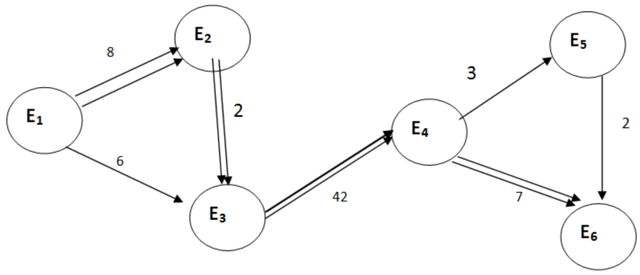
E5 = Drill obtained

E6 = Sowing finished/ completed (October 23)

Figure: Network Diagram of the farmer with expected time required for each activity



The diagram shows that the longest path which takes the maximum number of days is: E1 + E2 + E3 + E4 + E6, in the number of days: 8+2+42+7=59 days. The figure below shows the critical path for this example by double arrows



Time and motion studies in agriculture, which have occurred for a prolonged time, are similar to these techniques.

CPM has evidenced to be quite helpful in the construction industry and, hence, can be used with advantage for construction of huge storage plants for storage of agricultural supplies. In places where farmers depend on moneylenders and organizations like government for the supply of fertilizers, and rent machinery and equipment from for cultivation, a plan can be drawn to make the most efficient use of the machinery by larger number of members in a particular period of time. There are regions where the farmer has to wait for days and even weeks for his turn to fetch water from canals or tube wells to irrigate his crops and sustain them where this tool could be used to improve the situation. These techniques are of too useful only if put to use.

CONCLUSION

The use of operation research to the problem of decision making in agriculture has hardly been 20 years old. The most used technique in agriculture is linear programming. Besides linear programming, other model is time-network analysis. From the beginning of use of operation research in the First World War to the advance use of operations in various fields. Array of inventory control and other techniques are frequently used. Most of these tools can be used in all the fields of agricultural economic activities, viz., production, consumption, exchange and distribution. There is no doubt that the future would see increasing and diversified applications of operations research techniques in agriculture with the sudden increase in population and demand for more food. Every country is facing the problem of shortage of resources. Hence operation research can be used in agriculture in

- Optimum utilization of land and growing crops according to the given climatic conditions of the region.
- Optimum and correct utilization of water.

The past two decades have shown us the phenomenal growth of operation research in agriculture and as we agree the potential use of operation research in agriculture is vast and far greater than what we realise. Soon the scope of operation research would broaden from the use of agricultural industry to farm management.

If farmers are educated of the scope of operations research and enough brainstorming takes place on agricultural management by various economies of the world, the risk associated with this sector and the problem associated with the low returns can be solved and can pave way for a profit making occupation.

Thus, linear programming model and Network Analysis model is very useful mathematical models to enhance the production.

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