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Agriculture and Operations Research

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Abstract—*In this paper we will discuss upon the use of operations research techniques in agricultural area. Although the various techniques / models of operations research are very vast, but here we will put focus on only two techniques Operations Research those are use in Agricultural area.*

1. *Game Theory*
2. *Waiting Line Theory*

Operations research is a branch of mathematics which is used in various sectors. One such sector is agriculture sector. In this sector it is used in choosing the right type of grain, farm planning, cost minimization and profit maximization of farmers.

Keywords: *Game Theory, Waiting Line Theory, Agriculture, Operations Research, Profit, Optimal.*

INTRODUCTION

Agriculture has been long a low profitability and high risk occupation. Specific to the scenario in the Indian agriculture sector, the sector suffers loses, improper resource management and lack of modernization.

In this research paper, our 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 game theories, waiting line theory 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.

We will put focus on to techniques of Operations Research

1. Game Theory
2. Waiting line Theory.

GAME THEORY AND ITS' APPLICATION IN THE AGRICULTURAL SECTOR

The term game theory was invented by the mathematicians John Nash, John Von Neumann and the economist Oskar Morgenstern. Game theory is the study of mathematic models of human conflict and cooperation of humans in a competitive situation. Game theory is meant for situations where decision makers are affected by the interaction of other players and their own behaviour. Game theory is applicable to problem solving. Game theory captures real life concepts like "bargaining" and "reputation" in situations like a land owner and a potential renter bargain over a potential contract.

Game theory in agriculture is mainly used in fields of international trade and political economy. Besides these two sectors game theory is rarely seen in agriculture this is because it is difficult to use it as a basis of estimation. Game theory helps model situations that cannot be modelled without it to help evaluate its role.

Basic models

The Two-Person, Zero-Sum Game

Two players or persons oppose each other in this type of game each having a finite number of actions called a strategy set.

S1 = [a1, a2, •••, am] and

S2 = [b1, b2, ••• , bn]

Assuming s1 and s2 are strategy sets for players 1 and 2 respectively. The rule for the game is that the players must take one move at a time and the moves must be taken simultaneously.

Considering each player made a move there is a playoff. The playoff matrix shows the profit to player 1 for every strategic pair. Ojj . All possible pairs of strategies form a matrix of outcomes, (Oij) . The Oij (i = 1, . . . , m and j = 1, .. , n) entry in this matrix is the outcome of Player 2 choosing his ith strategy and Player 2 choosing his , jth strategy.

		Player 2		
		1	2	3
Player1	1	3	5	1
	2	6	-3	0

The above matrix is a pay-off matrix which shows the strategies of player 1 and 2. So we can read the above matrix as follows if player 1 plays strategy 1 the playoffs will be 3,5 and 1. And if player 2 plays strategy 3 the play-offs will be 1 and 0.

In the above example the strategy 1 of player 1 and strategy 2 of player 2 gives us the outcome of -3. The negative sign shows a loss for player l and a gain for player 2.

Thus the game is called a zero sum game because the gain of one player is the loss of the other. This theory points out the strategies that a player can play to obtain the lowest loss or the highest return. This is called the security level. The playoff matrix is always written in the viewpoint of player 1.

The Maxi- mini and Mini-maxi strategies

Given below is the playoff matrix of player A and player B

Player A's Player B's strategies Row Minimum (Maxi-mini)

Strategies

	T1	T2	T3	T4	
S1	5	8	7	9	5
S2	15	12	9	17	9
S3	11	6	8	7	6
Column		15	12	9	17

maximum(Mni-maxi)

Row minimum column or the Maxi-mini column symbolizes the minimum payoff for player A's strategies.

Player A has to maximize his gains and the aim of player B is to reduce his losses and risk.

So if a plays his first move that is S1 and B plays T1 the playoff will be 5 to A. so if a has to choose a strategy we will notice that A will choose to play s2 because in this case he is assured of a pay-off of at least 9. If he plays any strategy other than S2, his gain can be reduced to as low as 5 (if he plays s I). Thus the others are less than 9. Therefore 9 is the maximum of the minimum (called maxi-min) and S2 is As maxi-min strategy.

In the above table 9 is called the saddle point of the game as if you observe 9 is the maximum in its column and minimum in its row thus also called the value of the game where the Maxi-mini and Mini-maxi value is the same.

Game against Nature

The main application of the game theory in agriculture is done in the "game against nature". Nature out here can be defined as weather, insects, pests' diseases In plants, climatic conditions and social and political situations. Thus the term nature is applicable to all situations except when a farmer is directly in conflict with another farmer. When a farmer is against another farmer/ landlord it is called game against "person". The difference between nature and person being that against nature the farmer is the only one who makes losses/gains. Whereas against a person the famers loss will be the persons again and the other way around .Thus when we apply game theory to game against nature the pay-off matrix will always be in the view point of the farmer therefore all the operations shall be conducted on the rows and not the columns unless required.

DIFFERENT CRITERIA OF CHOICE WALD MAXIMIN CRITERION

This criterion assumes the farmer to be pessimistic and helps us find out the minimum return (security level). Wald creation act is the act of selecting the security level. Let's assume X1, X2,...Xm to be situations and Y1 , Y2,.... Yn to be states.

	Y1	Y2
X1	(2	3)
X2	(4	1)

We see that 2 is the security level for X 1 and I is the Security level for X2. In the above example if X1 are the farmer strategies and Y1 are the acts of nature. In the above example can be taken as a game the farmer is playing against nature. The game is exactly like that of a two-Person, zero-sum game. It can be shown that the maximum strategy for a two-person zero-sum game is the best strategy against the worst an opponent can do. Nature will not consciously do its worst against the farmer. Hence the Wald criterion is a model for decision-making under uncertainty. As we all know farmers with limited resources may go bankrupt and loose all that they have if an uncertainty.

Thus the Wald crition suggests various precautions a farmer could take to avoid uncertainties.

Wald crition would suggest growing alternative crops or growing mixed crops to ensure minimum fixed income every year. It may also advise to increase use of fertilizer to increase the security level.

Similar to the Wald Maximum Criterion are also the Laplace's criterion , regret criterion, Hurwicz' criterion decision models. Application of these various decision models to agricultural problems can result in recommendations suited to a wide range of farmer situations.

APPLICATIONS OF WAITING LINE THEORIES IN AGRICULTURE

Everybody is versed in the upheaval of waiting. It may be buying tickets for a cricket match, waiting for baggage at an airport, being put on hold by a customer care executive, in a line for car wash or in traffic. In general waiting line has these attributes:

a. Someone or something that needs the use of a service, often referred to as a 'customer'

b. The service

c. The idleness of:

   I. Customer to be serviced

   II. The service

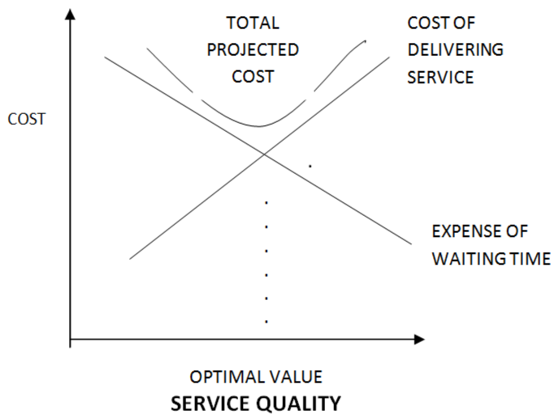
d. The definite function of providing the service

X axis represents service quality & y axis represents cost of providing the service.

As the service quality improves, the cost of providing a service will also increase. With an increase in service quality, the cost of waiting time falls as people or items will have lesser time to wait in a queue and they will be serviced quickly.

By adding the 2 curves, total projected cost is obtained.

The point of optimal value represents the most economical value with optimum total cost and service quality



The model can be illustrated with an example, showing how costs help to optimize service quality.

FEATURES OF WAITING LINES:

1. ARRIVALS:
   Arrivals depend on the following:
   a. Size of the calling population — Unlimited or Limited
   b. Pattern — Poisson Distribution
   c. Behavior — Balk, Renege, Jockey

2. QUEUE
   a. Length — Unlimited or Limited
   b. Discipline - FIFO or LIFO

3. SERVICE FACILITY
   a. Configuration
   b. Pattern — Constant or Random

SINGLE SERVER WAITING LINE MODEL

This model includes single-server, single-phase, single-line system.

The following assumptions are made:

1. The customers are patient and come from a finite population
2. Customer arrivals are reported by a Poisson distribution with an average arrival rate of (δ). The time between consecutive customer arrivals supports the exponential distribution with a mean of $1/\delta$
3. The customer service rate is recounted by an average service rate of μ (mu) & Poisson distribution. This means that the service time for one customer is followed with exponential distribution with a mean of $1/\mu$
4. The waiting line priority rule often utilized is first come, first serve basis

FORMULAE:

δ = mean arrival rate of customers (mean of customers arriving per unit of time)

μ = mean service rate (mean of customers that are served per unit of time)

p = the mean usage of the system

L= the mean number of customers in the service system

L_QpL the mean number of customers waiting in queue W^1 the average time passed waiting in the system,

$W_Q$$p^w$ the mean time passed waiting in queue

P_n (1p) p^n the probability that n customers are in the service system

EXAMPLE

The UMA Cinema at Naka No - 5 has a ticket counter to help customers purchase tickets. The customers form one single queue in front of the counter for assistance. Around 15 customers enter per hour. Customer arrivals are illustrated by a Poisson distribution. The server helps 20 customers per hour (calculated through an exponential distribution). Calculate:

a. The average utilization of the ticket counter server
b. The mean no. of customers in the system
c. The mean no. of customers waiting in the queue
d. The average time a customer passes in the system
e. The average time a customer passes waiting in the queue
f. The probability that there are more than 4 customers in the system

Solution:

Under the assumptions of single server waiting line model,

Average utilization: p = δ/μ = 15/20 = 0.75 or 75%

a. Average no. of customers: L = δ / μ - δ = 15/20-15 = 3
b. Mean no. of customers waiting in queue: L_Q = pL = 0.75 x 3 = 2.25 customers
c. The mean time customer passed in the system: W = 1/ μ - δ = 1/20-15 = 0.2 hours or 12 minutes
d. The mean time customer passed waiting in the queue: W_Q = pW = 0.75 (0.2) 0.15 hours, or 9 minutes
e. The probability that there are more than four customers in the system equals one minus the probability that there are four or fewer customers in the system. We use the following formula.

$P = 1 — \sum_{n=0}^{4} p_n = 1 - \sum_{n=0}^{4}(1-p)\ p^n$

$= 1 — 0.25(1+ 0.75^2 + 0.75^3 + 0.75^4)$

= 1 — 0.7626 = 0.2374

There is 23.74% chance of having more than four customers in the system.

APPLICATION OF WAITING LINE THEORIES & MODELS IN AGRICULTURE

Example :- SINGLE CHANNEL MODEL

Cotton is a cash crop, grown in many regions of India. Cotton is sent to various fasctories and mills. It is the producer's responsibility to deliver the cotton at the collection centres of the factories. He delivers it the cotton in trucks. But there is only one weighing machine so the farmer has to wait for long to get his cotton weighed and get the weight receipt which is taken to the cashier to receive his payment.

Let there be one service counter, Let the average number of arrivals be 30 trucks per hour. Let the rate of servicing be 40 trucks per hour. Then

Solution:

Under the assumptions of single server waiting line model,

a) Average utilization: p = $\frac{\delta}{\mu}$ = 30/40 = 0.75 = 75%

b) Average no. of trucks: L = $\frac{\delta}{\mu-\delta}$ = 30/40-30 = 3 trucks

c) Average no. of trucks waiting in queue: L_Q = pL = 0.75 x 3 = 2.25 trucks

d) Average time a truck passed in the system: W = $\frac{1}{\mu-\delta}$ = 1/40-30 = 0.1 hours or 6 mins

e) Average time a truck passed waiting in queue: W_Q = pW = 0.75 (0.1) = 0.075 hours or 4.5 mins

CONCLUSIONS

From the beginning of use of operation research in the First world war to the advance use of operations in carious field. Array of application where the use of operation research reaches is vast from education, health, welfare, urban affairs to even agriculture. 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 Game theory, simulation, time-network analysis, queuing theory, 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.

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