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Significance and Application of Operations Research in Agriculture

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Abstract: Agriculture is one of the most important sectors in the Indian Economy as a large percentage of total population are involved in it but it contributes to a very small part of the country's total GDP (about 18-20%). It contributes to such a low part due to the use of conventional methods of doing agriculture rather than adapting to newer and better methods of agriculture. Various factors affect monsoon in India- location of the place, type of soil and the amount of rainfall received.

Operations Research can be conducted in the field of agriculture to help improve the production methods so that the resources are efficiently utilized and the agricultural workers gain the highest benefit. The purpose of this research paper is to find the best possible solutions for the agricultural pattern by considering all the different factors affecting the production and sales of the materials produced. The different kinds of methodology used in operations research in agriculture are – Game Theory Model, Transportation problems to find the least cost of transporting the goods and Linear programming problems to find the most profitable crops and accordingly allocating resources towards it.

Keywords: Agricultural pattern, Production method, Transportation problem, Resource allocation, Game theory.

I. INTRODUCTION

The science of Operations Research (OR) was initially developed after World War-II as a operational decision making tool for military installations but today there is hardly any field left where operations research tools are not applied. It is a modern science that provides an insight into the application of optimization techniques. The decision makers are interested in maximizing returns or minimizing costs, to achieve economic efficiency. There are different techniques/models and operations research provides appropriate knowledge to apply these models in agricultural planning. These techniques take due care of the constraints/restrictions confronted in the real life situation in the agricultural sector. In the present day of growing global complexities, the operations research models are widely used in planning and management to achieve organizational and economic goals.

Agriculture is the most important sector of Indian Economy. Indian agriculture sector accounts for 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce. It is an agriculture based country, where more than 50% of population is dependent on agriculture. This structures the main source of income. The commitment of agribusiness in the national income in India is all the more, subsequently, it is said that agriculture in India is a backbone for Indian Economy.

Operations Research has been around in the agricultural and forestry management sectors since the fifties, approaching decision problems that range from more strategic sector- level planning to farm operation issues and integrated supply chain management. It has contributed significantly in economics and in agricultural economics.

In this paper, insights are given on the use of operations research in agriculture. The presence of OR in Agriculture and Forest Management applications is already extensive but the potential for development is huge in times where resources are becoming increasingly scarce and more has to be done with less, in a sustainable way.

II. OVERVIEW

It is controversial to use and apply quantitative models in the process of agricultural decision making. Models used were not very innovative and therefore had to use quantitative models in agriculture which were to be broken down into basic components and then can be solved by mathematical analysis.

There is a growing demand by agricultural policy agencies to evaluate the costs and benefits of alternative policy measures quantitatively. Operation research has been around in the agriculture sector since the 50's. Operation research techniques are very important because it helps us in using our resources optimistically and achieve efficiency in production of crops in agriculture. Through Operation research it helps us to calculate the profitability and also helps us in maximizing profits. In India, it came into existence in 1949, with the opening of an operation research unit at the Regional Research Laboratory at Hyderabad.

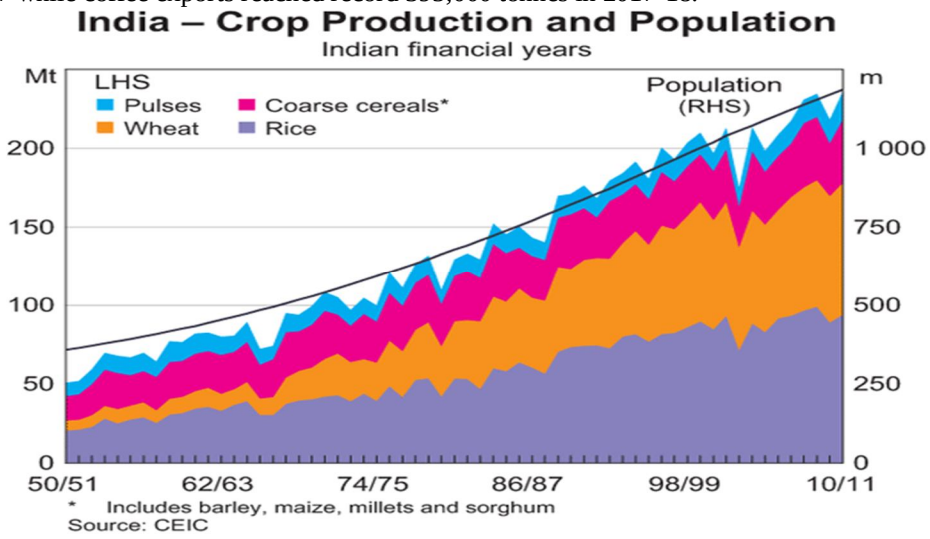
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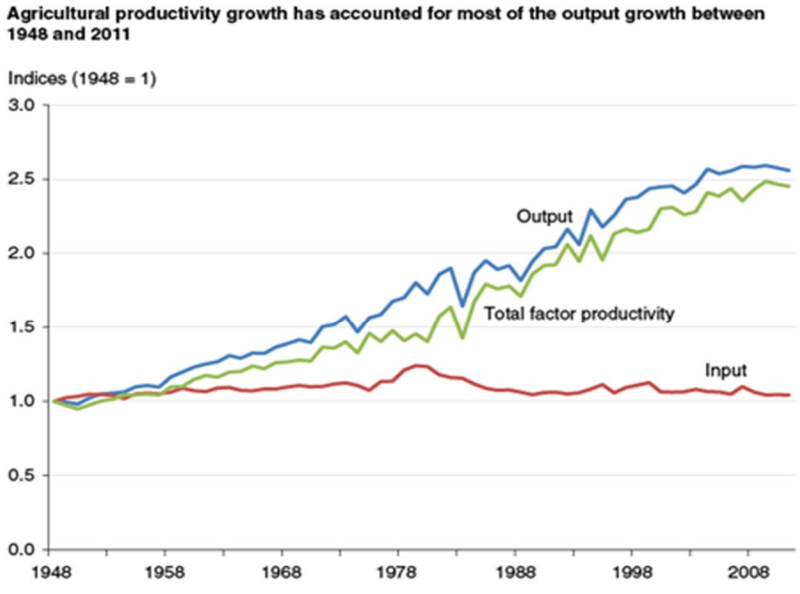
Presence of Operation research in agriculture is extensive but potential for development is huge because there is so much of scarcity due to which there are less resources available for usage and thus it has to be done in a very sustainable manner.

(Indian Agriculture and allied industry report, 2019) Agriculture is the primary source of livelihood for about 58 per cent of India's population. Gross Value Added by agriculture, forestry and fishing is estimated at Rs 18.53 trillion (US$ 271.00 billion) in FY18.

The Indian food industry is poised for huge growth, increasing its contribution to world food trade every year due to its immense potential for value addition, particularly within the food processing industry. The Indian food and grocery market is the world's sixth largest, with retail contributing 70 per cent of the sales. The Indian food processing industry accounts for 32 per cent of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. It contributes around 8.80 and 8.39 per cent of Gross Value Added (GVA) in Manufacturing and Agriculture respectively, 13 per cent of India's exports and six per cent of total industrial investment.

Total agricultural exports from India grew at a CAGR of 16.45 per cent over FY10-18 to reach US$ 38.21 billion in FY18. In FY2019 agriculture exports were US$ 38.54 billion. India is also the largest producer, consumer and exporter of spices and spice products. Spice exports from India reached US$ 3.1 billion in 2017-18. Tea exports from India reached a 36 year high of 240.68 million kgs in CY 2017 while coffee exports reached record 395,000 tonnes in 2017-18.





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III. RESEARCH OBJECTIVES

A. To design a mathematical solution for agricultural patterns to gain the highest benefits.
B. To create an effective and efficient agricultural pattern for proper utilization of the available factors of production.
C. To find the best transportation route in order to efficiently utilize the available produced by transporting them at the least cost.
D. To find the best possible combination of resources which will help him yield the highest returns.
E. To determine the most profitable resource and allocate sufficient funds towards its production and sales.

IV. RESEARCH METHODOLOGY

On the basis of the secondary research conducted, the group identified a pertinent need to address the issue of crop production and agricultural management in the Indian scenario. The topic was selected post intricate analysis and due to the current lag of Indian agricultural industry and its effect on the present day economic conditions.

A sum totally of 10 research papers and 3 news articles in the field of both Operations research and Agriculture were studied in order to derive findings and support our research efforts.

The following OR tools have been used to conduct research and obtain relevant solutions for the pressing problem and requirement of an advanced crop management approach.

1) *Game Theory:* In this paper, game theory models have been applied to the problem of decision making under uncertainty in agriculture. The group examines and compares the pros and cons of the conventional theories of choice in decision making in agriculture.
2) *Assignment Problem:* There are different methods for solving the assignment problems for finding out optimal solution of an assignment problem. This paper is concerned with the special class of allocation problems, where the objective is to find optimal assignment to the number of crops produced and their respective cost.
3) *Linear Programming:* Linear programming is a mathematical method for determining a way to achieve the best outcome (maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships.

The problems created here on are hypothetical and are employed as per convenience and understanding of the group.

The problems have been created and solved collectively in order to reach an optimal solution or rather a feasible resolution to the need.

V. LITERATURE REVIEW

OR/MS practice requires interactions with the agents that specify, design, build, and operate all the systems involved (M.A. Carravilla, 2013). (Ghosh Ahana, 2018,807)

The basic components of a decision-making problem can be grouped into (1) objectives, (2) a set of alternative courses of actions available, and (3) uncertainty. The problem of decision-making arises due to the fact that one's uncertain of the future. He has to take a decision in the present for the future in the realm of uncertainty (Agrawal, 1967). The time interval of crop plantation also matters. For example, suppose a dryland wheat farmer makes a decision each year on whether to leave a tract of land fallow or to plant it to wheat on the basis of soil moisture at the wheat-planting time (Burt, 1965).

Pertaining towards a decision to pursue farming for a living, a person has to make very many important initial and then day-to-day decisions of the following type:

Where to start farming? What should be the size of the farm? What type of residential buildings are to be preferred or made on the farm? What type of farming should he have, viz. grain farming, hog farming, dairy farming, beef cattle, or some other type? Quantity of resources should he acquire and in what quantities? Whether should he have one tractor or two, small, medium or large in size. What attachments and special machines he should purchase for his business? How should he finance his farm? How much should he borrow and how much should be his own investment? Of the borrowed capital, how much should he take for long-term, how much for medium and how much for short term periods? When should he borrow and at what terms? What should be the source or sources of borrowing? Once acquired, what allocation of his resources is most efficient? What should he produce, when and how much of each? What level of technology should he use? What operations should he perform, at what time and in what manner? Once the produce has been obtained, he has to decide as to what to sell, and how much to sell, when, where and at what prices? - (Agrawal, Ramesh Chandra, "Applications of operations research techniques in agriculture" (1967))

We have seen that linear programming is extensively used in almost all areas of human life. It is used to minimize the cost of production for maximum output. In marketing, it involves the selection of products, selection of advertising media. In the finance department, it tries to optimize the return on the investment of capital and the personnel department can appoint people of optimum

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skill at minimum cost in a very systematic manner. In transportation problems, linear programming techniques help in making transportation policies to reduce the cost and time of transshipment. In short, with the help of linear programming models, a decision-maker can most efficiently and effectively employ his production factor and limited resources to get maximum profit at minimum cost. He can also take quick decisions which are important in modern times because of any delay or postponement in it may give advantage to other organizations. This research was carried out to study the application of operations research on agriculture. Agriculture involves a lot of decisions that are to be taken right from what to produce and where to produce, to selling the produce. (Mehta, Kausha T, 2011)

In the initial applications to farm management, LPP could be characterized as a mechanized form of budgeting is devoted to problems concerned with the optimum organization of farm business. That is, the early attempts were to cover parts of the farmer's decision by budgeting (Hutton, Operations Research Techniques in Farm Management: Survey & Analysis, 1965). The first paper with an application of operations research in agriculture was published in the Journal of Farm Economics in 1954 (Heady, 1954), where Earl Heady finds optimal land allocation on crop planning problems by making use of linear programming problem.

One of the research paper referred to, proceeds by checking the efficiency of coverage. The paper assigns 4 different crops to 4 different states of India where the main occupation is farming, and through assignment problems, the observer came to a decision so as to grow which crop for minimizing land under cultivation as well as maximize the profits. (Baveja, Ghosh, Punjabi, Dang, 2018, pages 7-8)

The utility and applicability of operations research techniques in agriculture or in any other sector of the economy depends on its structure and level of development. For example, agriculture in India is entirely different from that in the United States both in structure and technology. The problems of Indian agriculture are low productivity, small size of holdings getting still smaller. American agriculture is highly mechanized, the size of the farm is increasing, the percentage of population engaged in agriculture is decreasing and smaller numbers of farmers are producing increasingly larger quantities of food and other agricultural commodities. Therefore, one technique may be useful to Indian agriculture, but may need some modifications before it can be applied to

American agriculture and vice versa. In the United States and other developed nations there are business firms that use computers to solve the problems of individual farmers. This facility does not exist in most of the developing countries and, therefore, it is possible that some problems requiring the use of computers may not be solved. But this should not be taken as a serious drawback. For example, in India, where an average farmer carries on subsistence farming on a small size of holding with meager resources, a computer may neither be required nor be feasible for him (because of high costs) for preparing farm plans. This could be taken care of by calculators. His farm plan would be rather simple because of the features of Indian agriculture mentioned above. The progress of operations research has been phenomenal. (Agrawal, Ramesh Chandra, "Applications of operations research techniques in agriculture" (1967))

The changing economic conditions over the past century, along with the changes in technology and developments in economic theory and quantitative methods, helped to shape the profession we currently refer to as the agricultural and applied economics (Alex McCalla, 2010)

VI. ANALYSIS AND FINDINGS

A. Game Theory Model

Game theory models deal with the process of decision making by two or more opponents having conflicting interests, the success of one is the failure of the other. For example, in chess, as in any other game, the aim of each player is to defeat his opponent, to inflict on him the greatest loss or to let him get away with the minimum of gain. (Agrawal, 1967)

There are different strategies each player adopts in order to win, let X and Y be two players and they have strategies A and B respectively and P be the payoff matrix , then game G = (A,B,P) is a triplet.

Example – X and Y are playing stone-paper-scissors, if both come with same outcome, X pays Y $5, and for remaining situation Y pays X $3. So the matrix would be,

	A1-stone	A2-paper	A3-scissor
B1-stone	5	-3	-3
B2-paper	-3	5	-3
B3-scissor	-3	-3	5

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B. AP in Agriculture

Taking a hypothetical example to understand the working –

Step 1 – Balancing – no. of rows = no. of columns

Production matrix (production per hectare)

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	7500	8000	8500	7000
Maize	9100	7100	8200	7500
Sugarcane	7800	9000	8500	8000
Cotton	6500	7500	8800	8500

Opportunity Cost Matrix

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	1600	1100	600	2100
Maize	0	2000	900	1600
Sugarcane	1300	100	600	1100
Cotton	2600	1600	300	600

Step 2 – Row minima

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	1000	500	0	1500
Maize	0	2000	900	1600
Sugarcane	1200	0	500	1000
Cotton	2300	1300	0	300

Step 3 – Column Minima

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	1000	500	0*	1200
Maize	0*	2000	900	1300
Sugarcane	1200	0*	50000000	700
Cotton	2300	1300	0	0*

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Step 4 – Schedule

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	7500	8000	8500*	7000
Maize	9100*	7100	8200	7500
Sugarcane	7800	9000*	8500	8000
Cotton	6500	7500	8800	8500*

C. LPP in Agriculture

Quantitative Measures of LPP in agriculture

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. (singh, 2018)

Mathematical formulation

Z = c1x1 + c2x2 + c3x3 + ……cnxn (maximize) Objective Function

a11x1 + a12x2 + …….. + a1nxn <= b1

a21x1 + a22x2 + …..… + a2nxn <= b2 Constraints

.

.

am1x1 + am2x2 + ……. + amnxn <=bm

x1,x2, …. Xn >= 0

Z = c1x1 + c2x2 + c3x3 + ……cnxn (minimize) Objective Function

a11x1 + a12x2 + …….. + a1nxn => b1

a21x1 + a22x2 + …..… + a2nxn => b2 Constraints

.

am1x1 + am2x2 + ……. + amnxn => bm

x1,x2, …. Xn => 0

Taking a hypothetical example

A farmer produces two fruits Apples(x1) and bananas(x2)

Apple require 1 labour hour and banana requires 2 labour hours, total labour hours available is 9. Banana requires 4 times the area as compared to apple, total area is 11 acres. Apples fetch $1 as profit whereas bananas $3.

Maximize Z = x1 + 3.x2

Constraints

x1 + 2.x2 <= 9

x1 + 4.x2 <=11

x1, x2 >=0

X1	0	9	0	7
X2	2.75	0	0	1

Maximum Profit when we make 7 apples and 1 banana, i.e. $10

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We can design a mathematical solution for agricultural patterns to gain the highest benefits which will help us to find out how can we solve the problems in the agriculture using Operation techniques. Mathematical models have been constructed for OR problems and methods. So that it becomes very easy to solve the problems using OR techniques.

Some of the OR techniques are as follows-

1) Linear Programming
2) Waiting line or Queuing theory Inventory control / Planning Game theory
3) Decision theory
4) Network analysis
5) Simulation

To create an effective and efficient agricultural pattern for proper utilization of the available factors of production. For that we can use Linear Programming problems which is extensively used which will help us in minimizing the cost of production for maximizing the output. With the help of Linear programming models, a decision maker can efficiently and effectively employ his production factor and limited resources to get maximum profit at a minimum cost. It will also help to take quick decisions which are important in modern times as any delay may cause an advantage to the competitors.

To find the best transportation route in order to efficiently utilize the available produced by transporting them at the least cost. This can be done with the help of a transportation problem by which we can identify that how can we be able to reduce our transportation costs and what kind of methods we should use to reduce our costs. With the help of this it makes us easy to find out how much quantity of resources should be allocated to and what procedures we can make to reduce our transportation costs.

To find the best possible combination of resources which will help him yield the highest returns. For this we can use Assignment problem to assign each of the following. For example

We have taken the following four crops into consideration:(i) Rice (ii) Maize (iii) Cotton (iv) Sugarcane

The states that these crops should be grown in are: (i) Andhra Pradesh(ii) Gujarat(iii) Haryana (iv) Madhya Pradesh

This help us to decide which crop is most profitable in which state and hence it helps us to maximize the profits.

To determine the most profitable resource and allocate efficient funds towards its production and sales. For this we can use the Transportation problem to maximum profit by changing the profit matrix into an opportunity loss matrix and then solving it by minimizing the losses to increase the profitability and thus after solving the problem using this method helps us to find the most profitable resource and also get to know where it has to be allocated and at what cost it should be done.

VII. CONCLUSION

This research paper discusses how a very pertinent but a very low profitable sector in India, which is agriculture, can use OR to not only decide which crop can be grown most sufficiently in which state but also can conclude which crop is the most profitable in the respective area. Two AP were used to calculate the above-mentioned criterias. In the first problem it was concluded that Rice should be grown in Haryana, Maize should be grown in Madhya Pradesh, Sugarcane in Andhra Pradesh and Cotton in Gujarat, and in the second problem it was concluded that Arhar, if grown in Madhya Pradesh was most profitable, Maize in Andhra Pradesh, Moong in Maharashtra and Cotton in Karnataka.

From these results, we can draw conclusion that if farmers in India make use of OR techniques, they will be able to figure out what the maximum revenue they can earn is and also how efficiently they can grow the correct crop in the correct state and climate, effectively. Upon immediate adoption, the agriculture sector will become very profitable and efficient, and it is bound to grow at a much faster rate than the current scenario.

From a humble commencement during the World War-I, OR today has grown into an extremely sophisticated scientific method of management and mathematics. It now requires a knowledge of advanced mathematical operation and analysis. Further research and advancements in computer science have rendered OR more operational and sufficiently useful.

New techniques and tools are being developed at a lightning fast pace and the applications of the existing tools are being tested under different sets of parameters and assumptions. Several of these assumptions may be realistic in agriculture. As this study indicates, most of these tools can be used with advantage in all the four fields of agricultural economic activities, viz., production, consumption, exchange and distribution. (Agrawal, Ramesh Chandra, "Applications of operations research techniques in agriculture" (1967))

By far, the final decision still lies with the human being and, therefore, this element is still the most significant part of the decision making process. It is necessary that these powerful tools are used judiciously.

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Indiscriminate use may lead to disaster. A tool, at best, is only as good as its user. But there is no doubt that the future would see increasing and diversified applications of operations research techniques in agriculture and other industries. One cannot help agreeing with Burt in that "Potential applications of operations research in farm management are probably far greater than we realize. If growth of linear programming uses over the past decade is any indication of what to expect in the future for other techniques, operations research is still in its infancy as far as farm management is concerned". We could possibly go one step further and broaden the scope of his statement by substituting 'agricultural industry' for 'farm management'.

VIII. CHALLENGES

A. *Challenges for Application Of Or In Agriculture*

1) *Natural Calamities:* OR models cannot take into account the damage done to crops by natural calamities like drought, floods etc. Hence application of such techniques can only be done under certain assumptions which limit us to find the perfect solution.
2) *Changes in Weather Conditions:* Changes in weather conditions have a direct impact upon the production of crops and it is a factor which cannot be controlled by anyone which makes it a limitation as to any effect of weather on production cannot be taken under consideration while applying OR techniques.
3) *Hikes in Fuel Prices:* In OR models where the technique is used to find the perfect transportation or to minimize the cost of transportation the changes in fuel prices which in turn leads to increase in the cost of transportation becomes a limiting factor.
4) *Demand for Products:* Agriculture is a highly volatile market which is led by the demand of crops and manipulation of such market is an easy task which results in hiked prices or very low prices which then discourages the production of crops. Hence, is a limiting factor while optimizing the production and allocation of resources. Changes in Government Subsidies and Policies: Subsidies offered to farmer and policies of certain states may change affecting the profit of the farmers and production of crops, another factor limiting the application of OR as it is dependent on the human behaviour and decision-making process.
5) *Strikes and Riots:* As discussed the human behaviour is almost unpredictable and highly volatile. Strikes and riots are the outcome of human behaviour and affect the transportation of crops and production as well being an important factor that limits the application of OR

IX. LIMITATATIONS

A. *Dependence on an Electronic Computer*

Optimal solutions in Operations research are found out taking into account many factors. These factors are huge and in order to establish relationships among these huge calculations are required and this can only be done using computers. Hence, dependence on electronic computers

B. *Not Quantifiable Factors*

A solution is derived from an Operations research technique only & only when all elements are quantified. If the elements/factors of the related problem cannot be quantified, the find no place in operation research models

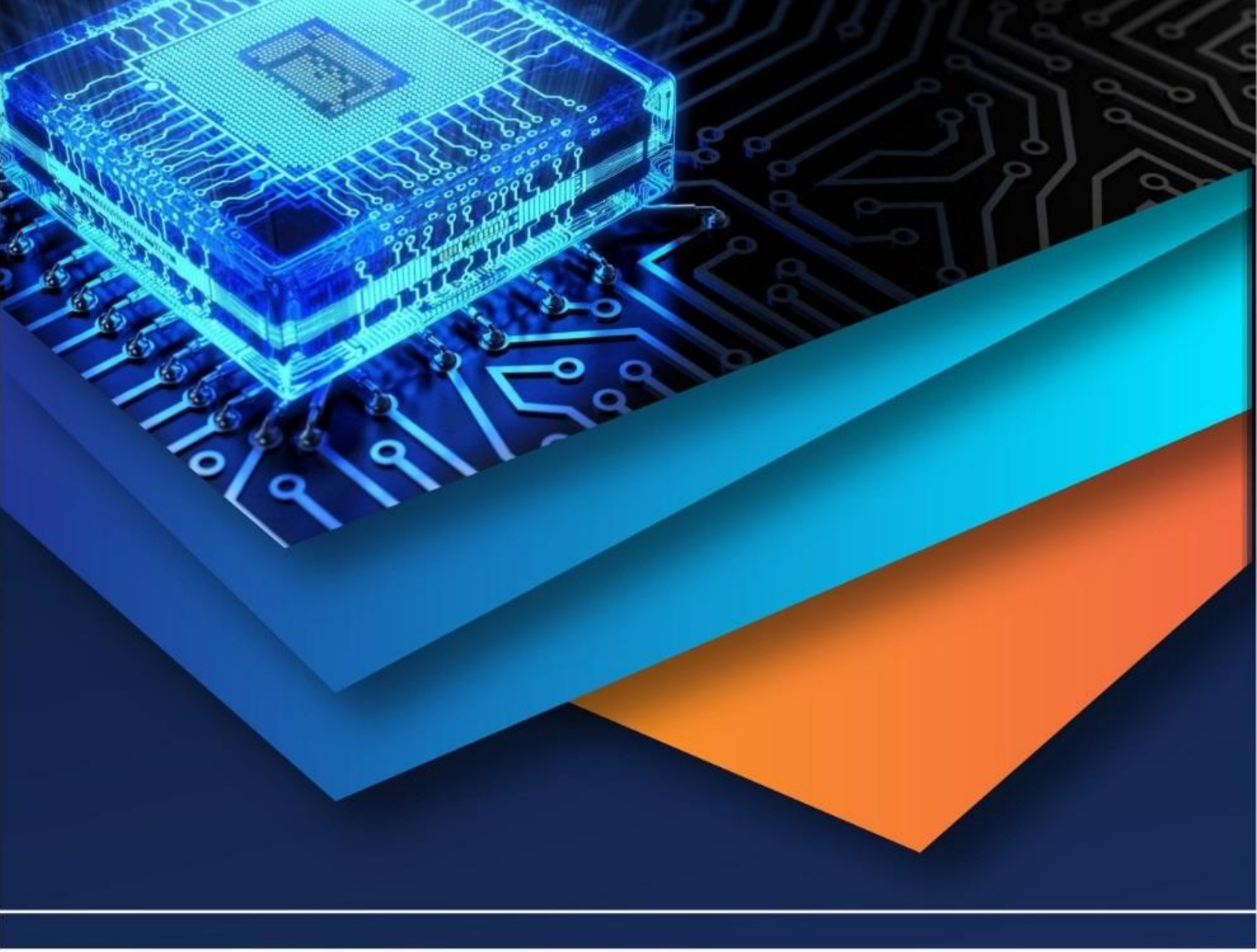
C. *Money and Time Costs*

Operation Research Techniques can burn a hole in your pocket as OR models is a costly affair when the data is subject to frequent changes and their incorporation can be heavy costs. Also, a good operation research solution is available only after sometime. Various models are considered for different problems and increments the cost

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