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Application of Operation Research Techniques in Agriculture

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Abstract: Operations Research offers useful scientific methods/tools employed in planning and administration of agribusiness. Right from 1954 researchers started analysing the applications of Operations Research in agriculture. Agriculture makes provision for food and is vital for the GDP of India with the ever growing population. This paper makes an attempt to use various Operations Research techniques such as Linear Programming Problems, Monte Carlo's Simulation and Replacement Theory to explain how the integration of these techniques in agriculture will not only help in reducing the prevailing issues in agriculture but also lead to higher efficiency.

Keywords: Agriculture, Linear Programming Problems, Simulation Theory, Replacement Method, Transportation Problems

I. INTRODUCTION

Data from the Food Corporation of India (FCI), the agency that buys grains for the central pool for public distribution and other welfare schemes, shows the combined stock of rice and wheat at more than 71 million tonnes (mt), apart from 8 mt of unmilled paddy – the highest for August. This is almost three times the minimum stock needed to run welfare schemes. National storage capacity is around 88 mt — 75 mt covered and 13 mt covered area plinth (CAP).

"Around 75% of wheat procured from Punjab is stocked under CAP, which is partly exposed to rains and weather. This time, more wheat will be exposed to rains as we expect heavy procurement," said the official. India has been agrarian economy at the start of its independence period, however over the years, has reduced its dependence on this sector for its growth. However, we cannot neglect the fact that, agriculture is the backbone for higher growth rates in the economy. Agriculture basically supports the industry by integrating foreword linkages and hence we can say that agriculture is the base of growth for any country, thus equal importance should be given to improve the state of agriculture in the economy. Currently, we can clearly see that a surge in onion prices and a ban on the export of onions have not only impacted the consumer but also the producers, leading to a lot of wastage and instability in the economy. In this paper, we have attempted to implement Operation Research Techniques on day to day problems experienced in agriculture to resolve the same. Both the above mentioned problems can be resolved through proper forecasting using Linear Programming Problems and Simulation theory, both being off-shoots of Operation Research Techniques.

Agriculture has for a long time been a low profitability and high-risk occupation. The sector is in such a bad state that thousands of farmers are committing suicide every year. This year, the agricultural sector is projected to increase by 2.1 percent. (K. N. Narayana, 2018).

This research paper throws light on the fact that since it is such an important but low-profit sector in India, farmers can use operations research to find out which crop is best suited for which climate and which state. Using operations research would not only help them minimize cost but it would also allow them to use their land adequately to the highest potential (H. Taha, 2016).

II. RELEVANCE TO THE INDUSTRY

Earlier, OR was mainly applied in managing of industries or firms. But the technique of OR model was applied for the first time in agriculture by Heady and Candler in livestock. Today OR tools are being applied in agricultural research and planning in the following fields.

- *A.* Optimum cropping plans for a region.
- *B.* Finding out optimum product-mix of different farm enterprises.
- *C.* In finding out capital, credit and inputs requirement.
- *D.* In designing feed rations for livestock.
- *E.* In designing transportation and marketing strategies.
- *F.* In storage and inventory management.
- *G.* To analyse the impact of new technology.

OR finds more significance in agricultural production economics due to following reasons

1) It takes into account complex system interlinkages.
2) It is free from estimation problems like auto-correlation, multi-collinearity, simultaneous equation bias, etc.
3) Estimation procedure is simple with the application of computer programming.
4) Based upon fewer assumptions and has more realistic and practicable solutions.
5) It provides scope for incorporating changes and, thus, is more flexible in methodology.

III. RESEARCH OBJECTIVES

A. To understand how various techniques of operation research can be used to achieve efficiency in agriculture productivity.
B. To elaborate on the fact that Operation Research has wider scope and is not confined industry and business
C. To outline the universality of Operation Research Techniques

IV. RESEARCH METHODOLOGY

This research paper has been formulated based on secondary research analysis by referring to various research papers written previously along with books written on quantitative techniques by various authors.

V. LITERATURE REVIEW

The science of operations research deals with attacking the problems, faced by the decision maker, through identifying the problem or problems in question, defining the alternatives available to him and also the various states of 'nature', apprising him of the payoffs associated with each combination of the elements of these alternatives and strategies and then suggesting, to him, the best course of action obtained through the use of logic, mathematics and other sciences.

This decision maker may be a business executive, a farmer, a physicist, an economist, a military officer, national planner or anyone else. (Ramachandra, 2001).

Some of the Operation Research Techniques like linear programming have been applied to a significant extent to farming as well. However, little has been done with regard to numerous other techniques to see as to how well they lend themselves to the decision-making process in agriculture, where snags are quite different from other trades as described above.

The objective of this study is to scrutinize the extent of suitability and applicability of some of the operations research techniques to the special conditions obtaining in process of decision making in an agri-business enterprise. As it would be rather bewildering to attempt to test all the techniques, this study is confined to the following:

A. Linear Programming Problems
B. Simulation Theory
C. Replacement Theory

VI. ANALYSIS

A. Linear Programming Problems

Linear programming is a method of mathematical programming that involves optimisation of a certain function, called objective function, subject to certain constraints and restrictions. Although it has a wide application, the common type of problems handled in linear programming call for determining product-mix that would maximise the total profits given the profit rates of each product involved and the resource requirement for each.

Thus, linear programming method is a technique for choosing the best alternative from a set of feasible alternatives, in situations where the objective function, as well as the constraints, are expressed linear mathematical function.

Here, we shall be using the graphical method as well as the simplex method to resolve two problems that a farmer or an entrepreneur engaged in an agri-business shall face on a daily basis.

This tool of forecasting and estimating data is of huge significance in agriculture as it helps in achieving maximum profits, or rather, minimum costs based on the various resource constraints available, thus helping to achieve efficiency in operations.

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1) *Illustration:* A farmer wants purchases 2 type of grains containing different amounts of 3 nutritional elements A, B, and C with the given cost and minimum requirement.

NUTRIENT	TYPE OF GRAIN		MIN. REQ
	G1	G2	
A	2	4	120
B	0	2	20
C	5	1	80
COST	25	15	

The farmer can make use of L.P.P to find out how much quantity should both grains be purchased to reduce his/her cost.

a) *Step 1.* Formulating The l.P.P

The above given information can be formulated in the following L.P.P, i.e., converted into an expression of numbers and variables.

Min Z = $25x_1 + 15x_2$

Subject to

$2x_1 + 4x_2 \geq 120$

$2x_2 \geq 20$

$5x_1 + x_2 \geq 80$

$x_1 , x_2 \geq 0$

Where, x_1 , x_2 represent the amount of Grain 1 and Grain 2 purchased respectively

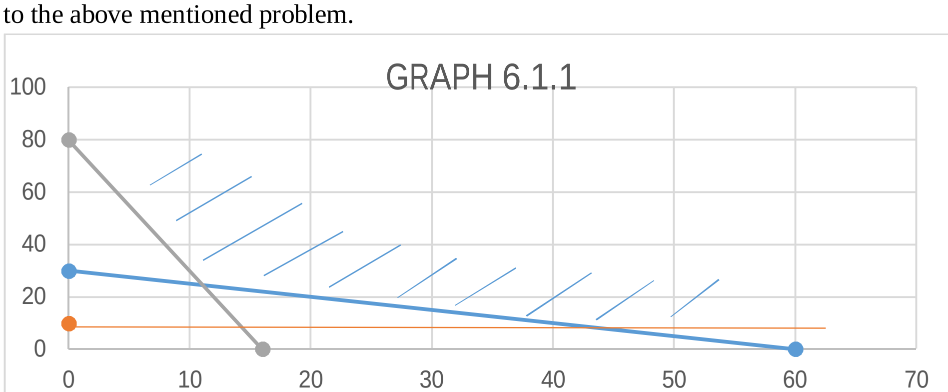
b) *Step 2.* Estimation of Cordinates

To plot the above inequations on the graph, we make use of the following table.

INEQUATIONS	EQUATIONS	x_1	x_2	REGION
2x1 + 4x2 ≥ 120	2x1 + 4x2 = 120	0	30	NON-ORIGIN
		60	0	
2x2 ≥ 20	2x2 = 20	0	10	NON-ORIGIN
5x1 + x2 ≥ 80	5x1 + x2 = 80	0	80	NON-ORIGIN
		16	0	

c) *Step 3.* Plotting the Graph

The following graph is based on the above found out coordinates, and based on the information, the below given feasible region contains the solution to the above mentioned problem.



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d) Step 4. Finding the solution

Now, we can place the coordinates seen in the shaded region into the objective function to find the minimum cost.

POINTS	CORDINATES	VALUE OF Z
A	(0,80)	1200
B	(11,25)	650
C	(40,10)	1150
D	(60,0)	1500

As we can clearly see, that the farmer should purchase 11 units of grain 1 and 25 units to grain 2 to incur minimum cost of Rs. 650

Thus, from the above illustration we can clearly see, how the graphical method can be helpful in finding the product mix to either maximise profits or minimise their cost. However, when we have to find a solution for more than two variables, it is not possible to make use of graphical method to find the solution, hence, when more than two variables are present, the simplex method is used to find the solution.

2) *Illustration:* A farmer wants to divide his land between 5 different crops giving different yield and requiring different resources. The following table represents the yield of the crops and also the various available resources that the farmer has:

CROPS	YIELD	LAND	LABOUR	CAPITAL	OTHER RESOURCES
RICE	102.85	773.4	22.03	10.08	13.09
MAIZE	114.84	941.84	45.74	14.1	12.07
WHEAT	263.5	823.13	63.47	17.33	18.08
PULSES	34.13	124.99	6.67	0.8	2.16
OTHER PULSES	98.26	89.2	10.91	7.32	9.07
AVAILABLITY		2752.56	2409	1069.7	111

(Extracted From CRISIL Report on Sustainable Agriculture)

As there are more than two constraints, we cannot use graphical method to find the crops that should be grown to achieve maximum yield, we shall make use of simplex method to find the same

Here, the above information shall be converted into an expression of variables and coefficients as follow,

Max Z = $102.85x_1 + 114.84x_2 + 263.5x_3 + 34.13x_4 + 98.26x_5$

Subject to,

$773.4x_1 + 941.84x_2 + 823.13x_3 + 124.99x_4 + 89.2x_5 \leq 2752.56$

$22.03x_1 + 45.74x_2 + 63.47x_3 + 6.67x_4 + 10.91x_5 \leq 2409$

$10.08x_1 + 14.1x_2 + 17.33x_3 + 0.8x_4 + 7.32x_5 \leq 1069.7$

$13.09x_1 + 12.07x_2 + 18.08x_3 + 2.16x_4 + 9.07x_5 \leq 111$

$x_1, x_2, x_3, x_4, x_5 \geq 0$

In order to solve the above problem, the following procedure is necessary,

a) Set up the inequalities describing the problem.

b) Convert the inequalities to equalities by adding slack variables.

c) Enter the equalities in a table for initial basic feasible solutions with all slack variables as basic variables.

d) Calculate Cj – Zj values for this solution where Cj is objective function coefficients for variable j and Zj represents the decrease in the value of the objective function that will result if one unit of the variable corresponds to the column of a matrix is brought into the basis.

e) Determine the entering variable by choosing the one with the highest positive value.

f) Determine the row to be replaced by dividing the quantity column by their corresponding optimum column values and choosing the smallest positive quotient.
g) Compute the evolutes for the entering rows. i.e the Old Element – (Fixed Ratio into Key Row element)
h) Compute values for the remaining rows.
i) Calculate Cj - Zj for this solution.
j) If there is negative value, then optimal solution has been obtained otherwise go to next step. Optimal solution is obtained when all the entries in Cj – Zj are negaitve or zero.

By solving the above formulated L.P.P using the solver available in excel, we get the following result, X3 = 2.57 acres of wheat and X5 = 7.11acres of other food crops

Thus, using the simplex method, the farmer can make maximum use of his available resources and obtain maximum yield by planting 2.57 acres of wheat and 7.11 acres of the other food crop.

Thus, with the help of the above two illustrations, we can see that, Linear programming problems can help a farmer or an enterprise, not just in determine the optimum product mix to reduce cost, but also helps in crop planting patterns and efficient utilization of available resources to maximize yield.

B. Replacement Theory

The theory of replacement deals with those situations where physical assets like machines, vehicles, or human assets need replacement over time. The assets need replacement because as they become old, they tend to become uneconomical due to involvement of increasing costs of maintenance. Also, new, and probably better equipment becomes available which is cost efficient that may facilitate and necessitate the replacement.

The above paragraph clearly explains the utility of replacement theory in agriculture –

a) To identify the appropriate time to replace the asset
b) To identify whether it will be cost efficient to replace the current asset with a new technology.

Replacement theory helps farmers as well as agro-business enterprises to boost their productivity by helping them understand the perfect time span for which the available asset should be used.

1) Illustration: The data on the operating costs per year and resale prices of a Mahindra and Mahindra tractor whose purchase price is Rs. 10000 are given below.

Year	1	2	3	4	5	6	7
Running cost	1500	1900	2300	2900	3600	4500	5500
Resale value	4000	3000	2200	1600	1400	700	700

The farmer wants to know when can he buy a new tractor of the same company and replace the old one. Also, after using the tractor for two years, TATA launched its own tractor with better efficiency levels. The optimal replacement period is 4 years with an average cost of Rs. 3600. The farmer is contemplating whether or not he should replace the current tractor with the new tractor.

Both these problems can be solved easily by applying the replacement theory. Firstly, to decide when to replace the Mahindra and Mahindra tractor with itself, we shall find the average cost of each year and the year having the least average cost shall be the optimum replacement period.

Year	Running cost	Resale value	Cumulative running cost	Loss on resale	Total cost	Average cost
1	1500	4000	1500	6000	7500	7500
2	1900	3000	3400	7000	10400	5200
3	2300	2200	5700	7800	13500	4500
4	2900	1600	8600	8400	17000	4250
5	3600	1400	12200	8600	20800	4160
6	4500	700	16700	9300	26000	4333.333333
7	5500	700	22200	9300	31500	4500

Table 6.2.1: Optimal Time For Tractor 1

From the table 6.2.1., we can clearly identify that the optimal time to replace the original tractor with itself, is the 5 year, as it leads to the farmer incurring the lowest cost for maintenance and replacement.

Secondly, as the minimum average cost of tractor A is 4160, whereas that of tractor B is 3600, the farmer should switch over to newer tractor for cost saving For, identifying when the current tractor should be replaced with the newer model of tractor in the market, we shall be making use of the following table:

YEAR FROM NOW	COST IF REPLACED	COST IF NOT REPLACED
0	3600	3100
1	3600	3500
2	3600	3800

Table 6.2.2: Optimal Time For Replacing The Old Tractor With The New One

The cost incurred if not replaced includes the running cost of that year and the opportunity cost incurred on the resale value.

The cost of replacement is lower than cost of non replacement in the end of 2^{nd} year from the current year. Thus, the tractor should be purchased at the end of second year from now or at the start of third year from now i.e. at the end of the fourth year of machine life. Thus from this illustration we can clearly see how replacement theory can be useful to the farmers in contemplating and deciding whether to replace machinery with a new one and if yes, then when would be the most optimal time to replace it to achieve efficiency in operations as well as reducing costs.

C. *Simulation Theory*

Simulation is a process involved with developing a model of some real phenomenon and then performing experiments on the model evolved with a view to predict the behaviour of the system over time. Thus, in simulation, a given system is copied and the variables and constants associated with it are manipulated in that artificial environment to examine how it behaves.

When we talk about the applicability of this theory in agriculture, we can say that it is useful in forecasting a set or a base of data for the future, basis on which future planning and execution can take place. This theory can be used to forecast future demand and supply as well as receipts and payments. It can also be used to determine at what does shall the firm face surplus demand or shall face overstock products. Simulation can be helpful in analysing and managing inventory to maintain optimal levels to reduce cost. However, it may be understood clearly that simulation is only descriptive in nature so that it describes the expected output for a given set of inputs. By itself, it does not provide any optimal solution.

1) *Illustration:* A farmer based on past data of 56 months has found the following probability of crops being damaged due to floods. Based on this data and using the random number below, he can forecast the data for a period of next 12 months, to accordingly understand, the loss that he shall have to incur if another flood happens. The loss per quintal is Rs. 200

LOSS IN QUINTAL	500	1000	1500	2000	2500	3000
PROBABILITY	0.01	0.05	0.07	0.33	0.18	0.36

Random Numbers are 13, 93, 45, 67, 8, 12, 16, 89, 99, 33, 78, 35

loss in quintal	probability	cumulative probability	random numbers
500	0.01	0.01	0
1000	0.05	0.06	01 to 05
1500	0.07	0.13	06 to 12
2000	0.33	0.46	13 to 45
2500	0.18	0.64	46 to 63
3000	0.36	1	64 to 99

Table 6.3.1.1 Generation of Random Numbers

Based on the above, table we create Table No. 6.3.1.2, wherein we forecast the loss that could happen due to floods in the next 12 months. The average loss in terms of quantity shall be 2333.33 quintals and that in terms of value shall be of Rs. 4,66,666.67.

Using the simulation theory, an enterprise can plan their decisions for future accordingly. Inventory related decisions can be easily taken to avoid over burdening of surplus products and excessive stocks and also help in maintaining optimum levels of production.

MONTH	RANDOM NUMBERS	LOSS IN QUINTAL	TOTAL LOSS
1	13	2000	400000
2	93	3000	600000
3	45	2000	400000
4	67	3000	600000
5	8	1500	300000
6	12	1500	300000
7	16	2000	400000
8	89	3000	600000
9	99	3000	600000
10	33	2000	400000
11	78	3000	600000
12	35	2000	400000
TOTAL		28000	5600000

Table 6.3.1.2. Forecasting loss for next 12 months using Monte Carlo's Simulation Technique

VII. FINDINGS

A. Operations Research is not confined to trade and industry and can be used to solve problems of all kinds of industry.
B. Constraint based problems can be easily resolved by converting them in a form of mathematical expression and then solving them using L.P.P
C. The most optimum time to replace a technology may not always be the year in which it has completely worn out. Also, it may not be necessary that the entry of a new technology will always reduce cost.
D. By converting the regular, daily problems into some form of simulation, it is easier to plan for the future by making minute changes in the model to achieve optimality.

VIII. CONCLUSION

Agriculture as a whole is filled with complexity and issues which can easily be resolved using operation research techniques. Operation Research techniques are extremely fruitful in helping agriculture to grow as a whole and provide solution bring it about as a larger contributor to GDP. The problems of storage issues as well as warehousing can be resolved using other methods such as transportation and assignment. Based on the above illustrations we can clearly identify that L.P.P is not only helpful in determining cropping patterns but can also help in reducing costs for the same. Replacement Theory can help the individual to plan his/her purchase of assets in future to save costs and not lose out on any productivity. Also, simulation theory helps an individual to find optimal solutions by converting larger models into smaller models. Thus the applicability of Operation Research has wide roots and can be used to achieve higher returns from the investment in agriculture.

IX. LIMITATIONS OF THE STUDY

A. We have assumed that all the natural conditions shall be constant through-out the year for determining the optimum product mix

B. Even though we have used simulation to predict losses due to floods, the frequency of natural calamities cannot be measured.

C. Agriculture is largely dependent on government policies and subsidies, a slight change in them, can lead to the farmer taking unrealistic decisions.

D. Many of these techniques require a lot of time to be implemented and a certain amount of investment in software, which is not possible for marginal farmers.

E. OR techniques provide a solution only when all the elements related to a problem can be quantified. All relevant factors do not lend themselves to quantification. OR model neglects all the factors that are unquantifiable.

F. 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.

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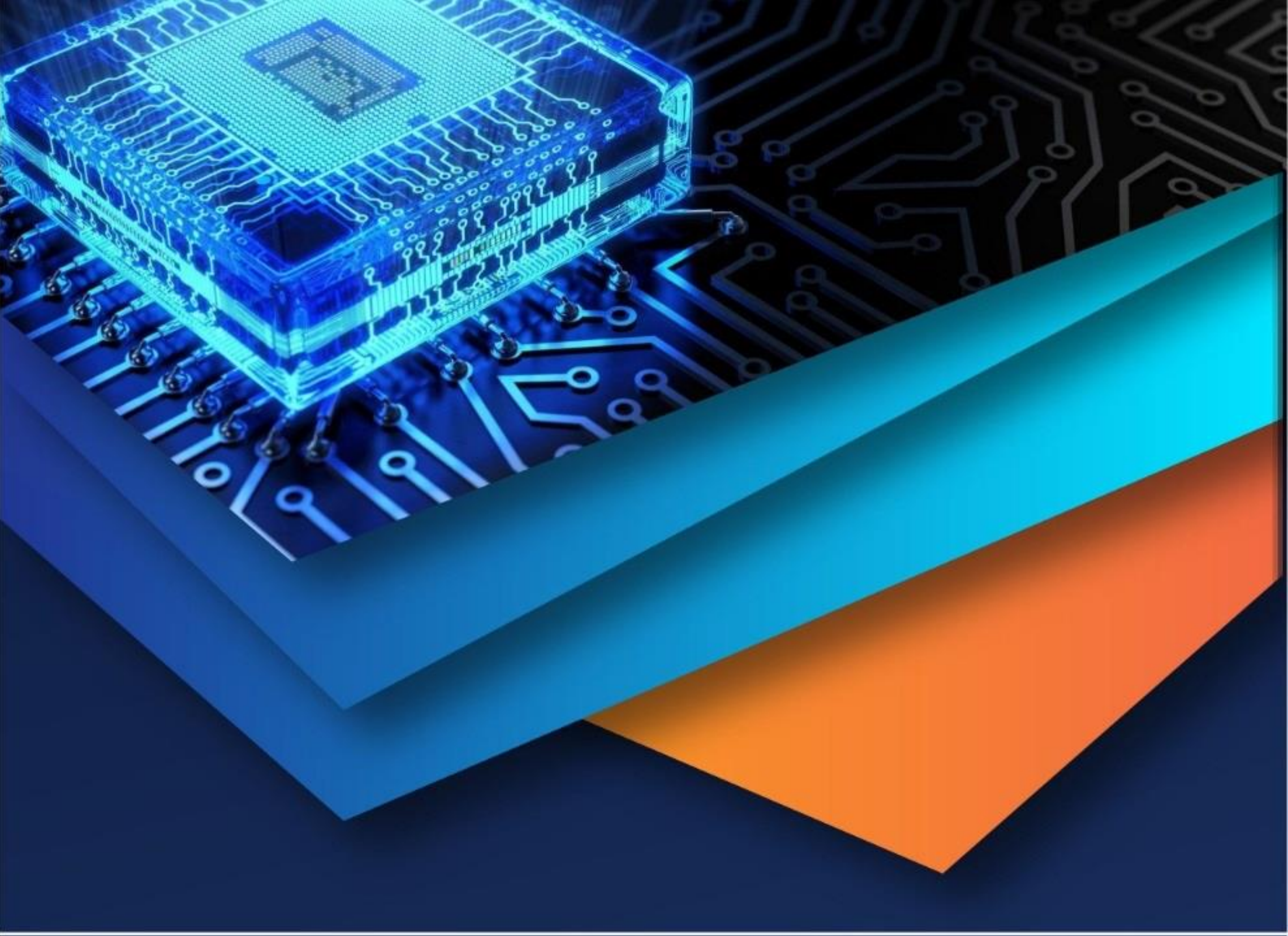

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