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Retail Location Selection using Operations Research

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Abstract: ***Almost all quality improvements come via simplification of design, manufacturing, layout processes and procedures. Instead of freaking out about these constraints, embrace them and let them guide you. We seek to use these constraints and turn them into optimal retail solutions which can ensure profitable construction and operation of retail outlets in strategic locations. Operational techniques have been used to not only maximise retail profits while minimising retail costs through quantitative data but also bridge the gap between customer preferences and successful retail strategies using qualitative data***
Keywords: Operations Research, Retail, Location Selection, Linear Programming, Catchment Analysis

I. INTRODUCTION

"There is a solid chance that you can be using square footage more productively. we don't need another retailer selling jeans and black pants, unless they bring a point of view and experience that no one else has" – rachel shechtman

The Indian Retail industry is one of the top five retail industries in the world and has emerged as the most dynamic and fast-paced industry. It accounts for over 8 percent employment and around 10 percent of India's GDP. There is wide competition between different retail formats who are looking for new and innovative ways to attract more customers. In spite of the rapid development, retail industry in India has faced several setbacks which are irreversible. According to estimates, over a dozen malls have been closed down or converted into office spaces in Mumbai, the National Capital Region (NCR) and Bengaluru in the last two years, with Mumbai accounting for half the closures.

Take Centre One for instance. The mall, which has a built-up area of 120,000 square ft and carpet area of 60,000 square ft and a 200-seat food court, could not find enough takers after swanky malls like Inorbit, owned by the Raheja group, entered the fray. "In 2003, smaller malls were fine. But in 2013 and 2014 when the average size of malls is 500,000 square ft and big malls are above a million square ft, smaller malls find it difficult to survive," says Anupam T, chief executive, malls, at Runwal group which runs four malls in Mumbai.

Operations Research starts when mathematical and quantitative techniques are used to substantiate the decision being taken. The main activity of a manager is the decision making. In our daily life we make the decisions even without noticing them. The decisions are taken simply by common sense, judgment and expertise without using any mathematical or any other model in simple situations.

But the decision we are concerned here with are complex and heavily responsible. Examples are public transportation network planning in a city having its own layout of factories, finding the appropriate product mix when there exists a large number of products with different profits. Various tools and techniques used in Operations Research include Linear Programming, Transportation Models, Game theory, Assignment Problems, Constraint Programming and so on, some of which have been studied in this paper for the purpose of deriving industry solutions.

Operations Research can be used in the retail industry in multiple avenues. It can be used to find an optimal retail location for the construction of a new outlet with the objectives of minimising the transportation costs and distance between the retailer and vendor, maximising the revenue and profits by mapping customer preferences in specific locations and formulating an efficient retail strategy accordingly.

Techniques like GIS Model, Catchment Analysis, Linear Programming, Assignments and Transportation or Network models can be used to achieve all these objectives with a distinct focus on both qualitative and quantitative data simultaneously.

In this paper, we seek to overcome the limitations causing shut-downs of retail outlets by using Operation Research techniques. These techniques can be implemented by the industry to ensure expansion and development while using the retail resources efficiently.

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II. OVERVIEW OF THE INDUSTRY

The retail industry has been growing along with mankind. With firms finding better ways to sell products to the consumers**,** location of retailing has evolved along with it too. Starting from barter system to trading with gold coins; from using money to credit based payments, the industry has seen it all. Initially retailing used to take place in a common market area where everyone would buy and sell. With commuting become faster, people tried to go further to buy their products, leading to further growth of the industry. Sizes of stores started increasing to attract more customers, and as per the product's requirements the placing of the stores changed.

With the 4th industrial revolution going on, e-commerce and internet are ruling the retail segments, leading to a massive downfall in the footfalls in physical stores. This has led to shopping in physical stores' expectations changing from just buying the goods and services to a multidimensional shopping experience. This has affected the location factors in the retail sector as people's preferences are becoming very difficult to predict. Hence operations research methods have been of utmost importance in deciding each and every step of retailing.

Locations for retailing have evolved gradually as said above, but researching about locations began barely in the 20th century, where retailers started using data of demand and supply in a particular location to estimate highest sales in the industry. With a lot of locations at hand in the 20th century, businessmen and economists started to develop their own methods (quantitative and subjective data models) to find the optimal location for their business. Huff's model considered store area, time to travel and importance of time to get the revenue in locations. While Porter's 5 force model compared subjective data to interpret optimal location. Since the evolution of technology and easy to operate interfaces, operation research has evolved drastically. With the help of extreme data generating and interpreting capacity of computers, scientists have developed various methods to minimise risks in deciding locations for retailers.

III. RESEARCH OBJECTIVES

The objective of our paper is to show the significance of operations research and its methodologies that can be used in the planning of the right location strategy for a shopping mall. Shopping malls are big business investments and the market share arising from the same is ever increasing. There is a lot of future opportunities here and so is grabbing investor's attention. hence it becomes important to choose an apt location for it to be put up so that the traffic inflow is maximum and th ereby the profits be maximum. There are a lot of other specific quantitative factors which determine the success of a shopping mall, which is what we will try to explore through this research paper.

A. To Understand

Through this paper we hope to understand how operations research can be used to optimize certain parameters which together will help us arrive to the best possible solution.

B. To Find

It'll help us find various methodologies and techniques which could be used to arrive at a particular solution. It will help us find the optimal location for a setup under a set of given parameters and also to find how operations research makes the process easier and more optimal.

C. To Elaborate

The paper will elaborate on different research methodologies used under operations research and the factors relevant in deciding a location strategy of setting up a shopping mall. It will briefly talk about how operations research can be used in finding out the optimal location for a shopping mall.

D. To Outline

The paper will provide a brief outline on different methodologies and techniques used under operations research. A theoretical approach has been preferred so that a generalized understanding can be derived out of the paper.

E. To Describe

It briefly describes how operations research can be applied to achieve the quantitative optimal in the real world where numbers do make a huge difference in almost every relevant aspect considered.

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IV. RESEARCH METHODOLOGY

We have conducted quantitative research in different aspects of retail industries and implemented models of operation research to understand the significance of the same in the growth of retail outlet. After implementing model, we have linked it to qualitative research to derive interpretations of different techniques.

The research paper, through the use of different models and techniques, tries to establish the importance of various factors that affect the location selection of malls. The models used are:

1) *Linear Programming Model:* The model helps in showing the importance of strategic allocation of available resources like investment, labour etc. in deciding the location of Malls.
2) *Geographical Information System:* This model shows the importance of geographical advantages that may benefit the malls. Time taken to travel, Availability of transport, Optimal area at minimal cost are a few that have a major impact on the benefits that an optimal location for a mall can provide.
3) *Transportation Problem:* The model benefits the malls by calculating the most favourable and economical distribution networks of stocks. It ensure that the malls have right amount of stock at the right time and at the right price.

V. LITERATURE REVIEW

A. *Michael Porter's Five Forces Model*

The five forces model of Michael Porter helps in the determining the attractiveness of the industry and better analysing the prospects of growth and opportunities by evaluating the competing trends and the aggressiveness of the rivalry amongst the existing competitors. It's a considerable strategic tool which is used for understanding the industry capability and threats which may limit the quality of the industry and prevent newcomers from engaging in a competitive battle.



The capacity of new entrant firms to get into the retail sector has considerably diminished in the last ten years. While large department store chains have slowly increased their number of locations, it has proved to become increasingly tougher for new entrants to find leasing and vendor deals with the manufacturers and the outlets. The leading department stores have grown their number of stores by an average of five percent.

Many consumers prefer to buy their preferred merchandise after having visited various stores in numerous locations for comparing the different prices and the different offers. This tells us that a customer does not remain loyal to one store for a long time. A retail store should focus on the importance of a good store location, properly identifying a genuine distributer in the closer vicinity and also the nature of products and availability of stocks.

The Digitalization process in recent years has also had a substantial effect on the structure of the industry. Due to an increase in ability of Information Technology, all the players in the market have increased access to extensive information. Due to the internet, the complication of irregular information decreases. On this basis, newer models of business can be made. Companies which were originally from outside the industry can change the structure of the industry. A good example of this is the case of shopping malls, in the past the management of shopping malls were able to get a competitive advantage due to their large number of product varieties and good locations. But due to digitalization, shopping malls have lost their place to electronic mediums of purchasing, thus rendering the shopping malls as a bit uncompetitive today compared to the past decade.

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B. Linear Programming Model

Linear Programming Model is a mathematical model which is used to optimize an objective function while taking into consideration specific objectives and constraints. Construction of retail stores in a variety of locations require huge investments, the return of which can be achieved in an efficient manner only if the resources are allocated strategically. Business managers face the problem of allocating scarce resources in a way to minimize cost and maximize returns. A linear programming model is used to achieve this objective through three components – an objective function, constraints and a non-negativity condition. Assumptions underlying linear programming are as follows:

1) Proportionality
2) Additivity
3) Continuity
4) Certainty
5) Finite choices

a) Case 1: Maximizing profit by comparing 2 potential locations

We assume the availability of 3 potential locations available for site selection, namely Location A, Location B, Location C. Statistics concerning the respective locations are given below:

i) Labour availability is plenty at Location B. Hence, Labour time per store for location B is twice as that of A.
ii) Total labour time availability is 9000.

Raw Material	Location		Availability
	A	B	
R1	2	4	5000
R2	2	2	7000
Profit per store	Rs.80	Rs.120	

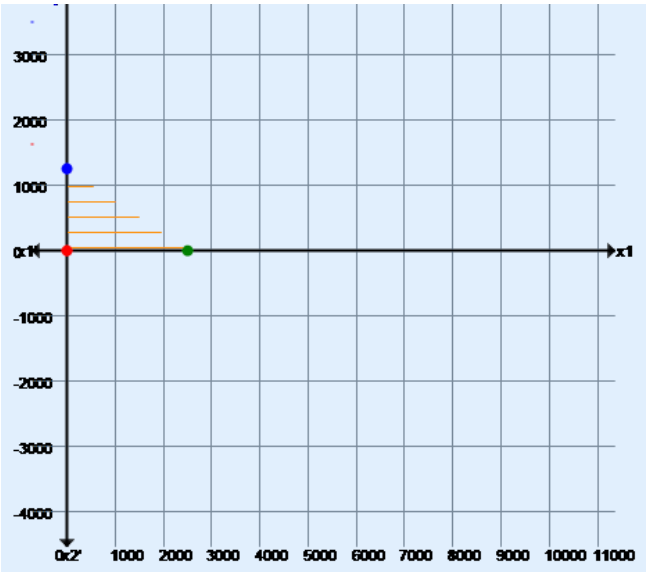
Objective Function: Maximise Z= 80x1 + 120x2

Subject to:

$2x1 + 4x2 \leq 5000$

$2x1 + 2x2 \leq 7000$

$2x1 + 3x2 \leq 9000$



This graph shows the feasible region constructed using the given constraints.

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Using the extreme point method, we get the following solution:

Extreme Point Coordinates ($x1$,$x2$)	Lines through Extreme Point	Objective function value $z=80x1+120x2$
$O(0,0)$	$4\rightarrow x1\geq 0$ $5\rightarrow x2\geq 0$	80(0)+120(0)=0
$A(2500,0)$	$1\rightarrow 2x1+4x2\leq 5000$ $5\rightarrow x2\geq 0$	80(2500)+120(0)=200000
$B(0,1250)$	$1\rightarrow 2x1+4x2\leq 5000$ $4\rightarrow x1\geq 0$	80(0)+120(1250)=150000

Hence, Location A is the most optimum location for the construction of a retail store as it generates maximum revenue from the scarce resources allocated to both labour and raw materials.

It is in this way that a Linear Programming Model can be used to derive the profitability of different alternatives for the purpose of optimum selection. Even though LPP is not predominant as a model in retail industry with an increased preference given to Huff's model, it can produce a variety of qualitative inferences from a restrictive quantitative set of data. Competition between different retail formats plays a huge role in the entry and exit of new retailers. In order to sustain in a competitive environment, it is important to build the store away from competitors who are close to us in a perceptual map. Also, it requires efficient utilization of resources to generate maximum profits. Linear Programming can be used in the following ways to ensure the success of a retail mall constructed in any area:

1) Maximizing store size
2) Minimizing competitors
3) Maximizing parking space
4) Minimizing costs

C. Catchment Analysis

It is of utmost importance for retailers to be easily accessible while also having a unique selling proposition which attracts maximum customer footfall throughout the year. **Catchment** is defined as the sphere of influence from which the retailer is likely to draw its customers. It is the area from where they expect to gather footfalls and run their business. Most widely used definition of various catchments is Primary, Secondary and Tertiary that attract 75%, 20% and 5% of the total visitors respectively.

Trade area is affected by a variety of factors such as population density of the area, customer preferences, and demographic segmentation of customers and so on. Large retail stores have large primary trade areas. For example: primary trade area extends up to 2 km for a regular store but the measurement might be wrong if the area is sparsely populated. In such a case, primary trade area should extend up to 5 km. Catchment analysis also determines customer needs and preferences which can be used to map out the retail strategy for a new store. An example of the same is given below:

	Less than a fortnight visit	Monthly visit	Once in 2 months	Once in 4 months	Rare visits
Store 1	8	28	26	23	14
Store 2	10	23	20	18	10
Store 3	5	14	16	12	10
Store 4	0	8	7	6	9

This table shows the frequency of customer visits in different grocery stores demonstrating a consumption patterns used to determine customer footfall. Store 2 has people visiting in less than 10 days showing an increased proportion of impulse or one time purchasers. Store 1 stands strong with maximum footfall in 2 or 4 months indicating loyal customers purchasing their regular grocery from the same store. Less than a fortnight visits come from primary trade area whereas rare visits come from tertiary trade area.

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	Men apparel	Women apparel	groceries	Stationery and toys
Store 1	14	24	58	16
Store 2	26	19	55	19
Store 3	22	25	48	17
Store 4	19	26	52	20

This table shows that Store 1 is located in an area where maximum customers are women who buy both apparel and groceries. A specialty store specializing in women's apparel should not be located near this store due to increased burden of competition. Store 3 on the other hand has a blend of both male and female customers. Hence, their retail strategy should be tailored to both the genders for maximum profits.

D. Application of Assignment Model in Retail Strategy Formulation

Assignment problem is a special type of linear programming model which deals with the allocation of various resources to specific categories for the purpose of maximizing profits and minimizing costs. Out of all the methods in assignment, Hungarian Assignment Method is the most efficient one to calculate assignments as it eliminates unnecessary iterative procedures unlike other methods. Surveys conducted for catchment analysis can be used in a more innovative and accurate manner by using assignment method to come down to the most preferred products in different regions without having to conduct an extensive behavioural analysis. An example of the same has been given below.

	Location A	Location B	Location C	Location D
Rank 1	Men apparel	Women apparel	Groceries	Women's apparel
Rank 2	Groceries	Stationary	Men's apparel	Groceries
Rank 3	Stationary	Groceries	Women's apparel	Stationary
Rank 4		Men's apparel		Men's apparel

This table allocates ranks to the different categories of retail products on the basis of customer preferences in the respective locations. In order to create an assignment problem, we make the following table:

	Location A	Location B	Location C	Location D
Women's apparel	-	1	3	1
Men's apparel	1	4	2	4
Groceries	2	3	1	2
Stationary	3	2	-	3

We minimize this assignment problem so as to allocate the product categories to locations based on the highest estimated rank. Any location with no preference to a product category has been marked by - to indicate no rank. After using Microsoft Excel's solver, we get the following assignments:

LOCATION A	Men's apparel
LOCATION B	Women's apparel
LOCATION C	Groceries
LOCATION D	Stationary

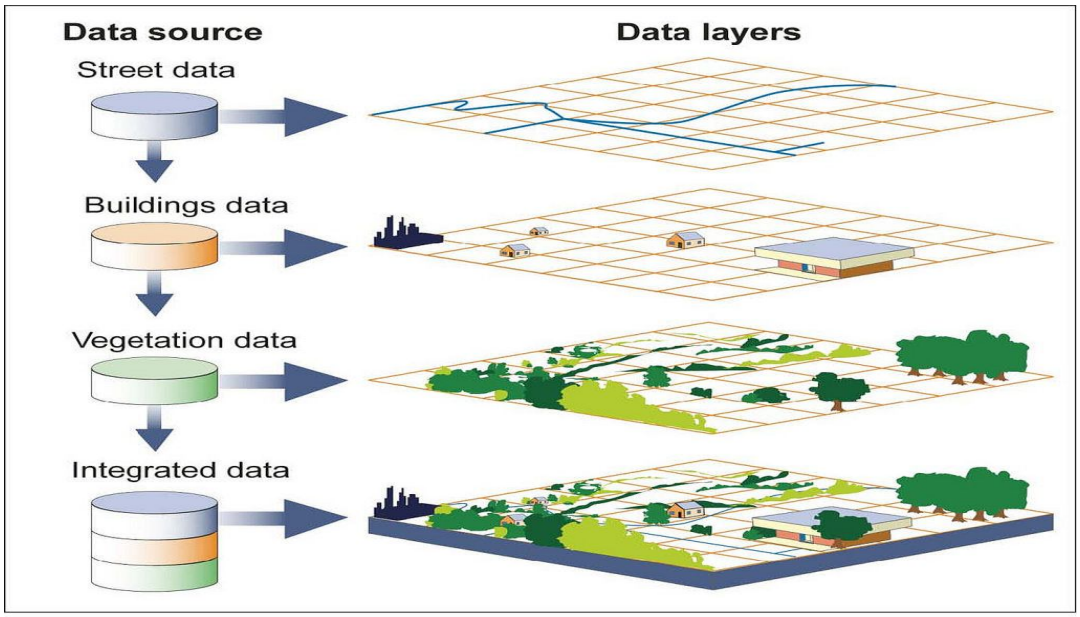
This solution shows that the retail strategy of location A should be formulated in a manner so as to improve the quantity and quality of men's apparel stock throughout the year as it seems to be the most profitable and preferred avenue among all the categories. Similar inferences can be deduced for other locations based on the solution. This is how an assignment model can be used in maximising retail efficiency by building a successful retail model. However, this method has its own limitations due to a more quantitative approach implemented in a qualitative context.

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E. The Geographical Information System

The Geographical information system is a decision making tool to analyse spatial data. It is a step ahead of cartography, which is the science of maps. The GIS is used capture, manipulate, store, analyse, and manage data.

The GIS builds on a basic map, like cartography, where additional data can be added as necessary. In the initial phases of GIS model's development, it was difficult to add multiple conditions because it was done physically on a map (2D techniques). As and how technology evolved, the model's application got easier, quicker and more efficient. More data layers can be added to the model using computers.



Source: GAO.

The modern age models are prepared on digital graphs that can store extreme amount of data and study it very easily and in a user friendly method. The applications now also make use of 3D structures to help the user.

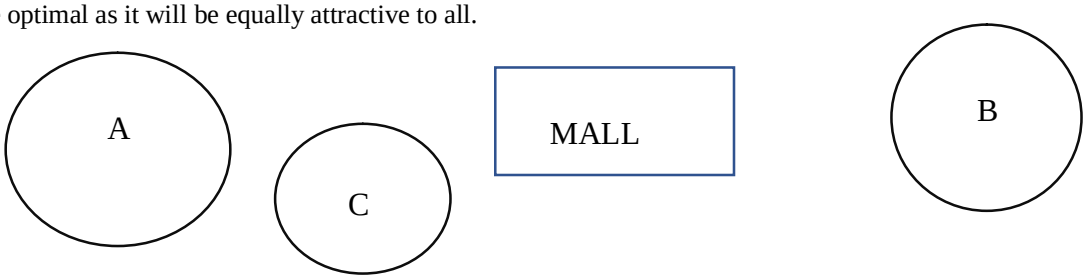
As can be seen in the above graph, the model has 4 different views of the same location and hence suggesting that data can be broken into more data, or multiple samples can be integrated to form something else.

GIS for solving locations for a retail outlet

As far as trends in shopping are considered in the modern age, people prefer shopping outdoors less frequently as compared to online shopping. The main factors to be considered for shopping in a mall/shopping centre are as follows

1) *Step 1:* Draw out the map of the Area of Focus (AOF)
2) *Step 2:* Create a database A database needs to be created in order to store and add more data, which will automatically keep updating the results that will be shown as the optimal location for the mall.
3) *Step 3:* Add all your conditions to the AOF

a) *Time to Travel:* As per the data available to the user, they should plot the user's time taken to travel from different localities or focused customers and try to minimise on that. Since the mall needs to be closer to every locality, the location at the centre is more optimal as it will be equally attractive to all.



As it can be seen, the mall is closer to all the 3 localities A; B; C, and hence attracts all the people equally.

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b) Availability of Transport: How good is the transport system available inn the AOF and each locality, based on that the location of the mall can be determined too. For example in the table given below, the transport from A is the best, and hence people will tend to travel further than people from C, where the transport it poorer. Hence the mall should be kept closer to C than A. But not too close to C so that transport from the mall back to locality is not affected.

Locality	Transport available	Distance of mall from locality
A	Best	Farthest
B	Good	Mediocre
C	Poor	Close

The willingness of locality A to travel further should also be considered. This too can be easily fed on to the map of AOF.

c) Optimal area at Minimum Cost: One of the main focus of any location over the years has been the cost. If the sales are high but costs are too higher, then it is a loss making location. Most places have different costs of purchase/lease. This can be put on the AOF to highlight places that are available at lower costs. This helps reduce the extent of the risk of the business.

d) Frequency of Shopping: The mall/shopping centre would want to maximise the number of people coming to the mall. This would depend highly on the frequency of shopping of each locality. When a customer is shopping more, he is a more valuable and profitable customer to the firm. And hence the firm will not want to lose him by keeping the mall further away from the shopper.

Locality	Frequency of shopping	Distance of mall from locality
A	Low	Farthest
B	High	Closest
C	Average	Mediocre

e) Amount spent on Shopping: A person may be living close to the shopping centre and maybe shopping more frequently than others, but the ultimate profit depends on the total sales value. Here people from A are spending higher amounts than the people from other two localities. This would attract the business to be setup closer to A, because they are more value-fetching to the firm.

Locality	Amount spent	Distance of mall from locality
A	Very high	Closest
B	High	Mediocre
C	Low	Farthest

4) Step 4: Finding the location

This GIS model will be able to collate all the above data into one single map of the area of focus and a very clear picture of optimal location will be provided. This will reduce the risk of failure of the business also.

F. Transportation Problem

The right stock reaching the right store at the right time is a very important task that many retail franchises fail to operate optimally. Even the few who do manage to do it incur unnecessary costs which would have been saved if they had made use of operations research and applied it to allocate optimally and save on costs. Transportation is a common problem that every retailer fails to prove efficient in. To show how this problem of transportation can be optimally solved using methods of operations research we make generalized assumptions to help understand how any problem of this kind can be solved.

A typical example would be to consider 3 storage houses from where stock is to be sent as A, B, C respectively and 4 retail stores where stock is to be received as 1, 2, 3, 4 respectively. The storehouses store the stock as follows A=500; B=300; C=200 and the stock demanded at the retail store is as follows 1=180; 2=150; 3=350; 4=320. The estimated transportation cost from each storehouse to each retail store is assigned in the matrix that will be used below as a step of the process to solve the problem.

1) Step 1: to check if the supply is equal to the demand

AD=180+150+350+320=1000

AS=500+300+200=1000

AD=AS (Balanced transportation problem)

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For better understanding we have taken assumptions in the way where supply = demand. If the case is otherwise (Unbalanced) then a dummy row or column is created to fill the gap.

The matrix:

TO	1	2	3	4	SUPPLY
A	12	10	12	13	500
B	7	11	8	14	300
C	6	16	11	7	200
DEMAND	180	150	350	320	

The highlighted numbers in the above matrix are the costs of transporting stock from the respective storehouse to the respective retail store.

Step 2: finding the initial basic feasible solution by using Vogel's approximation method which is also known as penalty method

TO	1	2	3	4	SUPPLY	I1	I2	I3
A	12	150 10	230 12	120 13	500	2	2	2
B	180 7	11	120 8	14	300	1	1	3
C	6	16	11	200 7	200	1	-	-
DEMAND	180	150	350	320	1000			
I1	1	1	3	6				
I2	5	1	4	1				
I3	-	1	4	1				

These are the allocations we have received when we solve the assumed problem with VAM method now as step3 of the process we have to check if this solution is optimal

Step 3: testing for optimality

TO	1	2	3	4	U_i
A	11 ***-1*** 12	150 10	230 12	120 13	0
B	180 7	6 ***-5*** 11	120 8	9 ***-5*** 14	-4
C	5 ***-1*** 6	6 ***-10*** 16	6 ***-5*** 11	200 7	-6
V_j	11	10	12	13	9440

Since the number of allocations = m+n-1 = 6 [m=columns; n=rows]

The solution is non degenerate

For allocations $C_{ij}=u_i+v_j$

Taking $u_1=o$

Since for all $\Delta_{ij}\leq 0$, the given solution is optimal and unique.

Total cost = 150*10 + 230*12 + 120*13 + 180*7 + 120*8 + 200*7 = 9440

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So this would be the optimal cost for the assumption made and this cost is unique, hence becomes the least possible cost that could be incurred for the above given data.

This above example is just one of the many ways of operations research that could be applied to solve actual problems regarding the location strategy of a retail store.

VI. FINDINGS

A. Linear programming model has been used to select optimal location by maximising profits while taking into consideration various constraints like raw material and labour availability.

B. Scope of linear programming in the retail industry has been studied which can be used to achieve retail success by maximizing store size and parking while also minimising costs and competitors. All these factors are considered extremely important to ensure the survival of retail outlets, especially malls, as indicated by the statistics. Hence, linear programming presents the solutions to such problems.

C. Catchment analysis has been used to determine the trade areas of specific retail stores as affected by multiple factors like population density and demographic segmentation.

D. Patterns have been drawn to map out customer preferences so that retailers can use such data to target marketing campaigns and product strategies so as to attract maximum custoner footfall.

E. Assignment problem has been used to further expand the results from catchment analysis. Solution of the problem has been used to demonstrate how the stores can identify their competitive advantage in terms of the product assortments they carry as per the customer needs and preferences.

F. Transportation method of problem solving is here used to determine the optimal allocation of units to be transported from a warehouse to a retail store.

G. The solution arrived is optimal which implies that the cost incurred to transport is the least possible cost incurred after all allocation requirements are fulfilled.

H. The GIS method is designed to find the optimal location using any number of conditions and can hence be used very efficiently using the new technology available to solve location based problems.

VII. CONCLUSION

As already shown in brief we see how different methods of operations research can be used in different ways to help with the location strategy of a mall. We have seen and explored a lot of areas in the current retail stores scenario which are not optimized to their potential like the transportation of stock to the warehouses or the usage of geographic information systems to set up the best location or be it the linear programming model to choose the most profitable one among different locations with a constraint on the labor availability or the concept of catchment analysis which helps in diversifying the customers.

It is evident after the research that operations research can be used in various real-life applications to optimize various functions performed. It can help save on lot of costs as shown in the paper and “Money saved is money earned” and also help in maximizing profits for a business by deriving the optimal combination of multiple quantitative factors that have an influence on the profits in any business.

All the operations research methodologies used have been briefly described in a generalized sense for better understanding hence meeting the main objective of the paper and thereby affirming that operations research proves very useful in various contexts.

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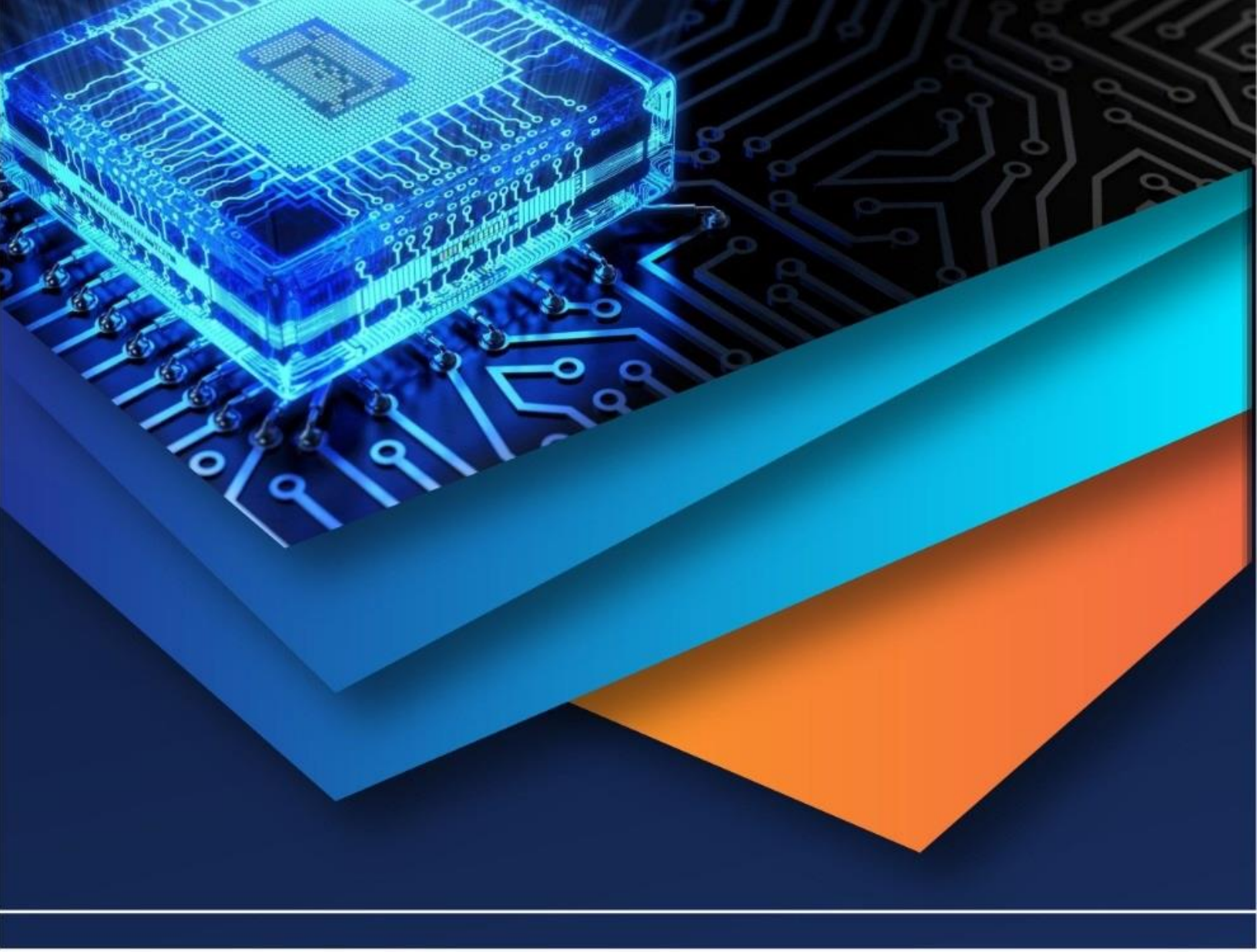
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