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Operations Research in the Automobile Industry

Mayur Madnani[1], Muskaan Sharma[2], Neerav Jain[3], Nikhil Agrawal[4]
[1, 2, 3, 4]*Narsee Monjee Institute of Management Studies Anil Surendra Modi School of Commerce*

Abstract: ***The objective of the paper is to improve the operational and production efficiency in the Indian automobile industry. This paper focuses on cost minimization by using a variety of mathematical models in a plethora of fields like supply chain management, cost management and estimation, etc. It offers the readers an insight into the various avenues through which the automobile industry could provide itself with a boost in these troubling times. A detailed analysis about the various models like genetic algorithm, discrete event simulation, etc. has been provided further in the study. The study shows how these factors help the Indian automobile industry optimize their cost structure and improving their efficiency in performing the tasks.***
Keywords: Automobile Industry, Cost minimisation, Supply chain management, Artificial neuron network, Genetic algorithm, Target cost management, Integer programming, Geometric programming.

I. INTRODUCTION

The Automotive Industry is an important segment of the global economy. With more than 70 million motor vehicles sold per year the automotive industry is one of the key industries of the world. While originally rigid labour division and paced assembly lines were employed to realize low-cost mass production of automotives, nowadays flexible mixed-model assembly lines make it possible to produce a large variety of customized products. The increased manufacturing flexibility, however, imposes new challenges not only for the design of the manufacturing system but also for the logistics coordination within global supply chains. In addition, novel planning and scheduling approaches are needed in order to manage the mismatch between increased product variety and the need to improve the utilization of the capital-intensive resources. (Hans-Otto Gunther, 2012)

For any industry to thrive, it needs to proficiently deal with its everyday exercises guaranteeing that it minimises it's costs and maximises it's profits. Particularly when we talk about the Indian markets where there is elevated level of rivalry on both domestic as well as international level, the importance of operations research in order to improvise on its efficiency increases. While the automobile industry is currently facing a hard time in the Indian markets, we have decided to focus on areas that account for the maximum money spent during the production and/or distribution in automobile and related industries such as, for example, supply chain management, cost estimation, inventory control, etc and recommend methods that will help lessen the expense of performing different tasks and yet won't influence its productivity accordingly improving the cost per benefit ratio just as the quality per cost ratio. We have briefly examined the working of every optimisation method and its relevance to the automobile industry.

A. Overview of the Industry

(Ferro, 2015) The Automobile Industry is comprised primarily of the world's largest passenger automobile and light truck manufacturers. Through broad dealership networks, most members of the industry sell vehicles in the global market, covering developed and emerging countries. Automotive manufacturers offer a variety of makes and models, though there tends to be limited brand integration at the marketing, advertising, and dealership levels. The bulk of these companies operate production facilities in multiple geographic regions.

Automobile manufacturers are subject to the demands of a vast international pool of customers. Economic conditions affect overall industry sales. Car lot traffic perks up during a boom period, and empty showrooms are commonplace during a downturn. Driving habits can change according to the economic cycle, and therefore, product lineups are always shifting, with new models, innovations, and technologies being developed to meet these demands. As a result, dealerships try to showcase a wide range of offerings, from small compact cars to sedans to light trucks and sport-utility vehicles (SUVs). Drivers' tastes and finances are varied and often change. Thus, showrooms will often have sports, economy, family, and luxury cars on hand to meet customers' desires. Luxury brands, with their high quality standards and advanced features, sell at premium prices and carry rich margins.

The price of gasoline (and diesel fuel) is an important factor influencing customer demand. Indeed, the rise and fall of gas prices since the 1970s has caused buyers to place varying degrees of emphasis on vehicle fuel efficiency, durability, engine power, and quality. Accordingly, market categories and product lineups evolve to meet customer preferences. Examples are crossovers, which combine the features of an SUV and the traditional car, and hybrids, utilizing the benefits of gasoline and alternative power (electric) sources. In order to stay profitable, manufacturers and dealers must properly gauge demand and carry the optimal mix of autos for each period in the business cycle.

To assist customers with purchases, and support sales, many companies offer low-rate financing programs and attractive incentives, such as discounts and cash back. Warranties, covering defects and repairs, are another means to lure drivers into showrooms. Another way to generate revenue is to provide vehicle leasing. A company can benefit from leasing via recurring payments over the life of one or more contracts and the eventual sale of the vehicle. Another good source of revenue is the sale of new or used cars to the government and to private fleet owners (e.g., rental companies).

The auto industry is both capital and labour intensive. These companies have to manage numerous costs and expenses associated with facilities, materials, parts, equipment, product development, and employment. At times, the prices of key raw materials, such as steel, can surge to record levels, requiring a nimble hedging strategy. Research & development and marketing and advertising expenses will have a discernible impact on the cost budget, as well. Too, given the seasonal nature of demand and new product launches, effective working capital management is crucial in supporting sales and controlling costs and expenses. The cost of labour has a big impact on competitiveness and profitability.

B. Research Objectives

1) To understand and analyze the different problems arising in the automobile industry.
2) To understand the various dimensions of the automobile industry.
3) To elaborate the uses of Operations Research in the Automobile Industry and to elaborate it's effectiveness.
4) To show how Operations Research helps in efficiently managing the operations of The Automobile Industry.

C. Methodology

The study was based on secondary research focusing on various techniques to optimise cost incurred in various processes whose sources have been mentioned in references. The various techniques used are namely Integer programming, Genetic algorithm, Artificial neuron network, Discrete event simulation, Life cycle assessment using geometric programming, Cost per program, Target cost management, and other related optimising methods.

II. LITERATURE REVIEW

Minimization of cost is very important for a company to survive in a market with extreme competition and in this paper, effective cost reduction is studied through studying the Capital Equipment dilemma which locks auto manufacturers into a cycle of declining cash flow and reducing competiveness. This dilemma is a deep cycle of limited capital budget, decision to re-tool existing Capital Equipment, highest cost per part and decreased market share and reduced cash flow. Overall, this causes a reduction in overall corporate value as the company is unable to compete on a global cost per manufactured part basis. A cost per part program is used in this paper which allows an automotive company to defy this dilemma by either implementing new technology, or supplier provided maintenance to insure outcomes and financing for new manufacturing technology. The result is a company that focuses on reducing total automotive manufactured cost per part allowing it to increase market share, corporate cash flow and overall corporate value. Another framework is Target Cost Management under which an organization designs ahead of time at the cost focus, item expenses, and margins that it needs to accomplish for another item. On the off chance that it can't make an item at these arranged levels, at that point it drops the structure venture totally. With target costing, a management team has an incredible asset for constantly observing items from the minute they enter the plan stage and forward all through their item life cycles. It is viewed as one of the most significant devices for accomplishing reliable productivity in an assembling domain. Target Cost Management is well known as the Japanese companies' competitive tool. It allows more relevant data collection because the entire organization can be investigated in depth and with great attention to detail. The first step is to review the marketplace in which the company wants to sell products. The design group needs to decide the arrangement of item that clients are well on the way to purchase, and the sum they will pay for those features. The group must find out about the apparent estimation of individual features, on the off chance that they later need to figure out what effect there will be on the item cost in the event that they drop at least one feature. At the end of this step, the group has a smart thought of the objective cost at which it can sell the proposed item with a specific arrangement of features, and how it must adjust the cost in the event that it drops a few features from the item. In the next step, the company furnishes the planning group with an ordered gross margin that the proposed item should gain. By subtracting the commanded gross margin from the anticipated item value, the group can without much of a stretch decide the most extreme objective cost that the item should achieve before it tends to be permitted into production. In the third step, the engineers and acquirement work force in the group play the main job in making the item. The engineers must structure the item to meet the cost objective, which will probably incorporate various plan iterations to see which mix of reconsidered features and plan considerations bring about the most reduced expense. Last

step involves the finalization and approval where the group is reconstituted to incorporate less architects and increasingly modern engineers. The group now goes into another period of diminishing production costs, which proceeds for the life of the item. In spite of the fact that administration may drop a design project that can't meet its cost objectives, this doesn't imply that the project will be for all time shelved.

A method that can be used for logistics optimization and in our research is Mixed Integer Non Linear Programming. It was used for reducing costs of packaging and transportation for cost minimization in obtaining the necessary parts for assembling by using the right sizes of containers, the quantity of necessary parts that can be filled in it and the number of days within which the parts should be ordered. The constraints necessary include factors which are including only a single type of container per period. The demand in the form of requirements and the supply which includes the boxes which are shipped should be equal and that the weight and volume of the necessary parts transported in the box should not be more than the maximum capacity of the boxes used. The parameters which are to be evaluated include of the volume of production, the weight and volume of all the required parts, the capacities of the containers used and the logistics cost in obtaining the containers. A few factors have to be assumed for the model to work, these contain the following; there should be no limit on the number of container types and the accumulation of the types of the necessary parts in the container which have to be at the place of transportation for exactly 2 days. This mode can hence help in cost minimization of inbound logistics by around 40%, but it does have a certain amount of limitations overcoming which can help expand the model. It can only work in the Just in Time inventory technique, i.e., ordering of stock at the exact time at which they are about to end which therefore minimizes inventory costs. It also does not include overhead costs, like the damage of parts during transportation.

Another important model that deals with cost minimization and the issues of understocking and overstocking is Inventory Optimization Model by using Lean Manufacturing System. It also deals with waste reduction. The gaps of the previous model can be covered by the help of using outbound Logistics which is the broad area of study under this model. This model is taken in this case to optimize the inventory of Mahindra which has three plants where engines are assembled- Nashik, Zaheerabad and Hardwar. The parts from which are transported from Igatpuri. Maximum cost arises in transportation to Hardwar because of the large distance between and hence there is a high amount of inventory kept hence increasing its costs where an average is taken to be 23 days. This cost can be minimized by using the following assumptions- Transit lead time should be between kept almost the same, production quantity to be 10 per day, only 204 engines should be sent from the Igatpuri plant, not more than 14 dispatches should be dispatched in a day and 47 empty pallets should be sent back every day Haridwar to Igatpuri. Costs can be minimized by increasing manpower, outsourcing activity, changing transport companies, usage of bigger vehicles, scientific research into reducing weight and volumes of pallets. The major solution is increasing capacity of transportation vehicle from 70% to 100%. There do exist some gaps like the involvement of a large number of agencies, which can be reduced by bringing everyone to a common platform. All issues of this model can be reduced by using proper softwares to prevent any disparities from the usual parameters. Now considering the current scenario, where the automobile industry is facing a slowdown, it is very important for the warehouse managers to improvise their efficiency as the warehouse serves as a buffer in balancing out demand and supply. Of all the cost incurred in warehouse operations, the majority of spending is on order picking. There are various approaches to order picking process of which, storage assignment, order batching and routing are considered the most important. Time interval and storage location proximity considered to get exact solutions for batching and routing problem in the warehouse are the two significant factors that need to be kept in mind while optimising the storage location assignment and order picking. “First, we represent an integer programming formulation that optimizes batching and routing problem together. However, due to the need for short computation time in real world problems, we also developed a genetic algorithm to approximate the results. Differently from previous studies genetic representation of solutions in Genetic Algorithm, designed in this paper, are encoded through order locations. The main advantage of the algorithm is the quick response to production orders in realtime applications. The solutions showed that the proposed approach based on Genetic Algorithms can be applied and integrated to any kind of warehouse layout in automotive industry. These models can be used by similar automotive manufacturers’ warehouses effectively to reduce their supply chain costs.” (Ene & Öztürk, 2011). The combination of integer programming and Genetic Algorithm provides a better solution to storage location assignment problem and has been a widely used technique when it comes to order-picking process.

The automobile sector is also heavily dependent on its suppliers in delivering of parts and could fail in delivering its customers in absence of timely deliveries. The copula approach is used above to determine the dependence. Copulas are used to describe the dependence between random variables and are common in high dimensional statistical applications as they offer estimation of distribution of random variables through predicting marginal and copula individually. With the applicability of copulas, Li’s default model is used. Li introduced a simple copula approach to model default dependencies between defaultable entities. This model is

used as a starting point and apply it to the context of default dependencies in supplier portfolios. However, this approach differs from Li's approach as instead of investigating default times for credits, it uses default times of suppliers. To successfully use this method to study the supply chain, 3 input factors are necessary namely 1) the dependence level between suppliers in the portfolio represented by the rank correlation Kendall's, 2) the default intensity of each supplier and 3) an appropriate copula representing the dependence structure. However, this research is limited by several simplifying assumptions because without doubt, in some cases a supplier would definitely benefit from other factors such as realization of economies of scale, default of a competitor, takeover of business etc. Another thing to consider is the sustainability in the supply chain model. The methods mainly used in sustainable supply chain management is based on the models of Geometric Programming. Geometric Programming is a method of a mathematical programming that is used in a variety of optimization problems and fall under signomial problems. It is used to solve practical problems of large scale and quantifying them into an optimization model. The research paper deals with sustainable supply chain management. It focuses not only on reducing costs but also reducing emissions. Supply chain management aims at providing the logistic aspects of the production process in the company in the most efficient way. This means suppliers, manufacturers, customers are involved in the supply chain activities including the ones involved in the automobile industry. In this research paper the automobile industry in Germany is taken into consideration and how they implement sustainable or green supply chain management for their inbound and outgoing logistics as well as in production. The method used by many in the German automobile industry for this SCM was Life cycle assessment in which it measures or evaluates the impact of the goods, services and processes involved regarding goods and services on the performance as well as on the environment. LCA uses Geometric programming to estimate the impacts of certain activities with constraints. In the German automobile industry for example Volkswagen used LCA in order to evaluate its logistics management whether inbound or outbound. Accordingly they made improvements in order to reduce emissions. For instance they replaced petroleum based heavy vehicles for bio gas based ones in case of short distance shipments of logistics. As the LCA showed that this would reduce the emission and harmful impact to the environment by reducing CO2 emissions by 20% and indeed it turned out to be true. An alternative method that is used to implement Green supply chain management in the automobile industry is the combination of using generic algorithm and fuzzy algorithm which gives an in depth analysis and solutions of various optimization constraints. Also LPP that is linear programming is an alternative.

Another useful process used in the automobile industry is Simulation. It 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 systems over time. Simulation divides itself into discrete event simulation and continuous simulation. Continuous simulation studies the process which is susceptible to analysis using the differential and difference equations, such as stability of various ecological systems, chemical synthesis, oil refining, and aerodynamic design of vehicles. Discrete event simulation studies the process in which many of the most important variables are integer values, and hence not susceptible to examination by continuous equations. Such processes almost invariably involve queuing, and the variables of high interest include current and maximum queue lengths, number of items in inventory, and number of items processed by the system. This helps in reducing lead times of holding Inventory like steel and oil, can help increase productivity and in some cases reduce floor space requirements For manufacturing processes of vehicles hence in turn reducing costs. The alternatives to simulation techniques are that can be applied is Binomial/Trinomial trees and other analytical techniques which is not as time consuming as simulation as these don't require an extensive search for optimal values of controllable variables.

Foreseeing the future prospects, as the industry faces a huge set back, innovation is the most prominent solution that would help companies counter the issue. While the companies find innovation in their products, knowing the estimated costs helps the companies manage the trade-off between product cost and performance. While there are various models that can be used in order to estimate the cost of product namely, Analogy-based techniques, Parametric models, Engineering approaches and newly designed Artificial neutral network; each model is used under different circumstances. We have had an in-depth study and comparison between Parametric model and newly designed Artificial neutral network (ANN). In parametric model, cost is expressed as an analytical function of a set of variables that usually consist some features of the product such as performances, morphological characteristics, type of materials used. These analytical functions are usually named ''Cost Estimation Relationships'' (CER). Talking about the ANN model, the model is inspired from human brain and has two components: a structure of densely interconnected elements called neurons and the connections between the neurons called synapses that could have different levels of electrical conductivity, which is referred to as weight of connection. An ANN reacts to inputs by performing the sum of the weighted impulse of the neurons: the result activates one or more specific output neurons which provide the answer of the net. Like the human brain, an ANN needs to be trained, which means that it needs to store knowledge by means of the elaboration of a set of training data (also called patterns), which represent the experience ''cumulated'' by the ANN. This training campaign allows the

network-designer to ‘‘fine tune’’ the weight of the connections between neurons, by storing the specific knowledge included in the patterns. Moreover, one of the most important characteristics of ANNs is their ability to infer from their knowledge the answer to questions (inputs) that they have never seen before. “The choice of the predictive model is generally based on the classical cost/ benefit ratio: in this sense, the regression models have often been preferred. But the more recently developed ANNs seem to represent a valid alternative, especially when the CER form is not known, and cannot be logically argued.” (Cavalieri, 2004).

III. LIMITATIONS

A. Limitations in the field of Operations Research

1) *Non-Quantifiable Factors:* OR techniques provide a solution only when all the elements related to a problem can be quantified. All relevant variables do not lend themselves to quantification. Factors that cannot be quantified find no place in O.R. models.
2) *Distance Between Manager and Operations Researcher:* O.R. being specialist's job requires a mathematician or a statistician, who might not be aware of the business problems. Similarly, a manager fails to understand the complex working of O.R. Thus, there is a gap between the two.
3) *Money and Time Costs:* When the basic data are subjected to frequent changes, incorporating them into the O.R. models is a costly affair. Moreover, a fairly good solution at present may be more desirable than a perfect O.R. solution available after sometime.
4) *Implementation:* Implementation of decisions is a delicate task. It must take into account the complexities of human relations and behaviour.

B. Limitations Faced by us

1) *Formulation of Research Objectives:* Deciding the right research objective can be difficult since the research paper is based on it. The objectives formulated need to have a balance of narrow as well as broad objectives.
2) *Limited Data Available:* Since only limited data is available on the internet, the biggest limitation for us was finding the necessary data regarding the automobile industry.
3) *Time Constraints:* Time constraints also played a significant role as one of our limitations. Since a deadline had been imposed, we had to complete the paper before it.
4) *Lack of Technical Knowledge:* As this is the first time we are writing a research paper, there was a lack of technical knowledge among all of us. However, this paper has helped us improve our knowledge.

IV. CONCLUSION

A brief analysis of the papers leads to the conclusion that the usage of certain methods: target cost management, artificial neutral network, genetic algorithm, discrete event simulation, , mixed integer non-linear programming, inventory optimization model, cost per program and geometric programming helped in understanding the optimum utilization of resources in the Automobile industry. With the declining of Automobile industry in the Indian market, it’s necessary for the companies to study and accordingly work on the least cost and maximum profitability of their products. This paper gives a useful insight on the different aspects of Supply Chain Management being vital in the Automobile industry. The future researchers should aim at conducting researches based on underused methods for scope of further development in the field. Although other models are available for the purpose but the given models used in our paper, are effective in analyzing the reduction of costs by utilizing the resources optimally.

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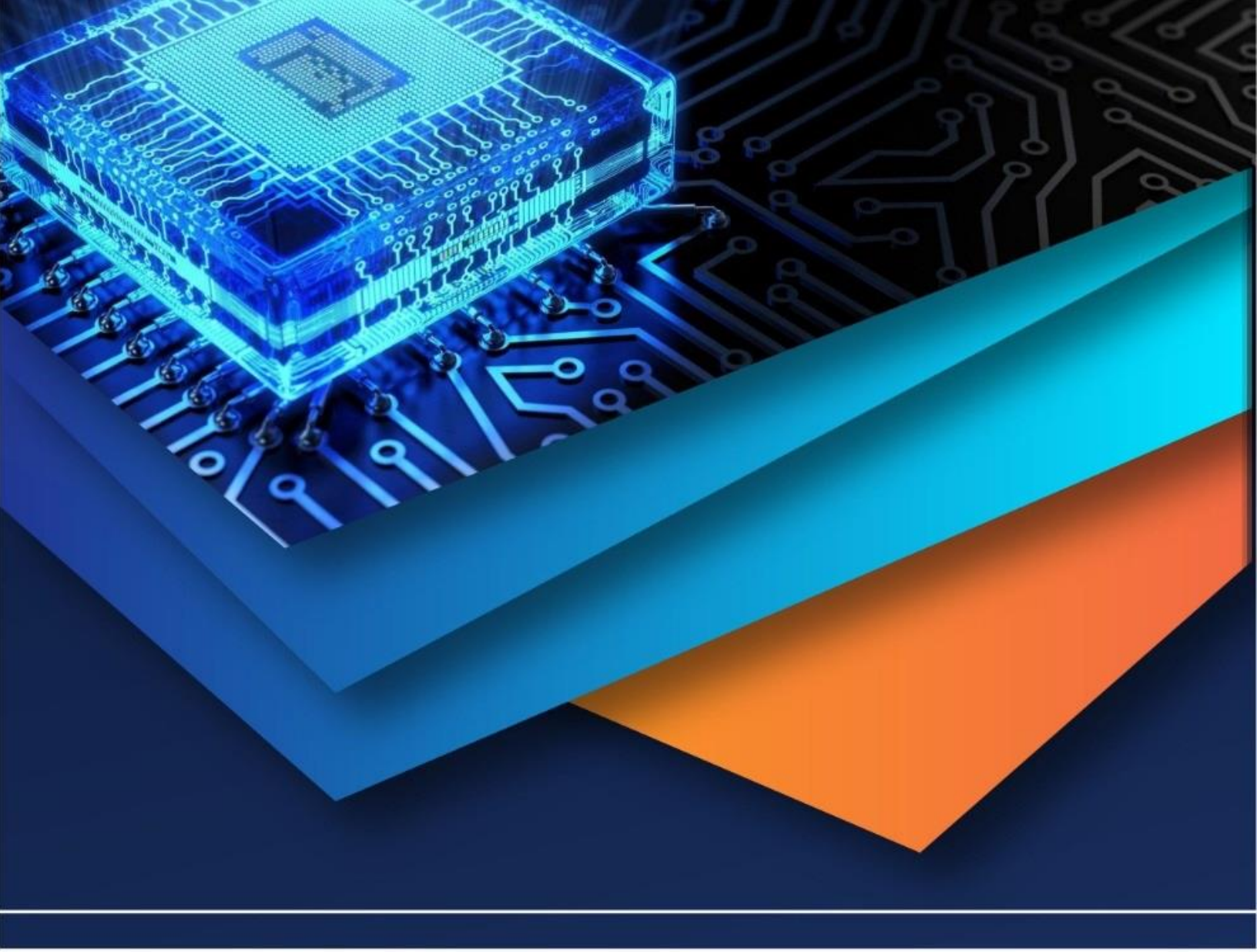

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