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Operations Research in Automobile Industry

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I. INTRODUCTION:

The greater manufacturing flexibility imposes additional constraints on both the manufacturing system's design and the coordination of logistics within global supply chains. To handle the conflict between the requirement to better utilise the capital-intensive resources and the need to enhance product variety, new planning and scheduling techniques are also required. New planning and scheduling methods are also necessary to address the conflict between the need to better utilise capital-intensive resources and the demand to increase product variety.

If an industry wants to prosper, it must successfully manage its daily operations to reduce costs and increase profits. Given the intense domestic and worldwide rivalry in the Indian markets, operations research is increasingly necessary to increase efficiency.

II. OVERVIEW OF INDUSTRY:

The automotive industry designs, develops, manufactures, markets, and sells automobiles and is one of the world's most important economic sectors in terms of revenue. The term automotive industry does not typically include industries dedicated to automobiles after they have been delivered to the customer, such as repair shops and motor fuel filling stations. The global economy includes the automotive industry as a significant sector. The automotive industry is made up of a diverse group of businesses and institutions engaged in the design, development, production, marketing, and sale of automobiles. Additionally, it is the sector where companies spend the most on R&D.

III. OBJECTIVES:

The need of operations research to improve efficiency rises, particularly when discussing the Indian marketplaces where there is an elevated level of domestic and international competition. The team has decided to focus only on the operations that account for the higher spending in the automotive industry and related industries, such as, for example, supply chain management, cost estimation, inventory control, etc. and recommend strategies that will help reduce the cost of carrying out various tasks.

IV. LITERATURE REVIEW:

Humans are not the only ones who experience the phenomenon of waiting. When facilities are limited and cannot meet the demand, bottlenecks form, resulting in queues. To show relationship of cycle time between large and small production, and it helps to determine the amount of work in progress in production using the queuing models. Applying the queuing theory in the assembly line is to assemble the process in the manufacturing plant by using analytical model of the theory which can help to increase the efficiency and production system. It helps by obtaining analytical results of performance such as average waiting time, expected length of queue, average number of customers or parts in system and probability of experiencing delays. To avoid a mix of manual and autonomous vehicles in a mixed environment, which could have a negative impact on road user interactions and jeopardise road safety. As a result, this can be solved using algorithms capable of analysing and reproducing human decision-making processes. Because much of the works have been focused on highway rather than urban traffic scenarios, autonomous vehicles in urban traffic must determine the level of cooperation of other vehicles, which can be done using the Game theory-based decision-making model for lane changing in a congested urban area. As a result, this theory enabled autonomous vehicles to change lanes using tactical level-algorithms such as modelling human behaviour and

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making dynamic decisions without risk. The reliability and prediction accuracy could be improved by evaluating the decision-making process throughout the entire lane-change action with a fixed "n" millisecond time step. This can be applied to both congested and uncongested urban areas.

Difficulties of uncertain usage variations, part to part variations and many other can be overcome using the Prognostic algorithm. General motor developed a technology named Proactive alert as this uses analytics of vehicle performance data and helps removing these issues. Algorithm like these can determine the forthcoming failures and then warns to the driver. The tool not only detected the issue but also identified the vehicle which has the fault. This drastically reduced the number of customers impacted. It helped customers to find exactly what they are looking for and similarly to dealers to find what customers are looking for and be satisfied with profit margins. Constructing a consumer choice model to capture consumer choice dynamics and solving an unconventional optimization problem embedded with a nonlinear choice model.

Question of "how to maximise profits but with minimised costs" is also of at most importance in such an industry. Target costing is such a concept originated in Japan, emerging around the 60s. In American terms it is also mentioned as "value engineering," initially developed at General Electric, a concept that tends to maximize product attributes while minimizing their costs. It simply means lowering the costs of a production without compromising the quality of the product. Toyota, the Japanese automobile industry uses this technique, by setting goals for cost reduction and then tries achieving new targets through design changes that will accomplish the cost reduction goal. Toyota vigorously compares its old and modern designs and makes the judgement, to guarantee reduced cost after implementing the new technique. Toyota achieved a higher level of profitability by changing the product & production design so that they produce lower priced and more efficient products.

Inventory management gets tedious and an impossible job for any industry. Over inventory or under-inventory, both is a quite common difficulty in an automobile industry. ButToyota uses the Kanban processing, which is a chain process in which orders flow from one process to another, the production or delivery of components is pulled through the production line, in comparison to the traditional forecast-oriented method where parts are pushed. This system has become well-known internationally for managing small quantities of inventory and thorough rationalization. One major feature of Toyota Production System which is "Just-in-Time Production" states that each process should supply necessary parts in necessary volumes at the necessary time. The Kanban system follows a set pattern making it an effective system. We also see that, there is complete utilization of machines, they do not sit idle, hence are utilization is maximum. Which means that loss of resources of man, machine utilization is almost zero percent.

For an automobile industry to survive the challenges it brings along with it, simulation is a method of solving such issues by designing, constructing, and manipulating the real system.The government of India took a decision to entirely skip the regime of emission standards when it was announced that BS IV will be shifted to BS VI in 2016. Also, this had to be done by 2020, i.e., in 4 years. Not only stringent measures for this but also next-level OBD which is onboard diagnostics and RDE which is real driving emissions were also imposed, and had to be ready by 2023. Given with the limited availability of prototypes, limited vehicles, and limited time, it is always a hard challenge to deliver test results validating different scenarios and executing automation. Passenger Vehicle Business Unit which is the validating team of Tata Motors, came up to a conclusion to use a combination of HIL system and compatible LABCAR models, ECUs, which are the engine control modules, would be connected to LABCAR. ECUs are like a network. At the end concludingly we see that the benefit of an accurate closed-loop simulation is the option catering to different conditions such as high speeds, higher RPM for longer periods and so on. The team could conduct several automated tests faster in the testing system which otherwise could have required protracted manual tests.

The lifecycle of a production facility is divided into four stages: conceptual, design, operation testing, and fully operational. Typically, the simulation procedure is carried out during the operation testing phase. The model that was run and examined during the launch phase will change over time, intoseveral related and comparable models. the supply chain becomes more aware of simulation capabilities, making small specialised automotive part suppliers, for instance, as likely to employ simulation profitably as the major OEMs already are. Shifting the use of simulation from external consultants and specialised internal workers to line employees who continue to get training and assistance from the consultants and internal experts.

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The main problem faced by Honda EV vehicles is that the time taken to charge the vehicle fully and the energy which is not optimized to the fullest. Different algorithms were proposed for EV charging schedule optimization, like evolutionary algorithms, dynamic programming, and non-linear programming. However, if the underlying optimization problem can be formulated in linear form – what is often the case – mixed integer linear programming (MILP) is typically employed for its solution. The focus is to minimize the utilization of energy, Minimizing the involved electricity cost and finding the smarter way to charge the EV vehicles. Through this the charging time taken is low and at the same time the run time is increased. Even though this method is bit complex, it is used for the optimization. The default parameter settings of MILP solvers are usually in a way, that a good average performance is achieved on heterogeneous problem instances.

In automobile distribution network optimization,the problem is that all the automobile companies started with the strategy called as BTO (build to order) network. It is basically when a customer wants to purchase a vehicle, the vehicle will be built only after the order is placed. This made a problem in time taken to deliver the vehicle and logistics also had issues. Since, the time taken by the companies to deliver the vehicle, customers started to cancel their bookings. This was the problem faced by many automobile companies.The problem is formulated as Linear Integer Programming models and an efficient Lagrangian heuristic algorithm is developed to solve them. After the calculation of various divisions like unloading time, the assembly time, the sorting time, the upload time, and the time spent on administrative procedures using the help of these tools, solution was found. Using these, the time spent on various division is reduced by which customers can get their vehicle as early as possible.

Issues of logistics and supply chain in Maruti is another big yet solvable one. Due to the logistics the cars were not delivered to the customers on time. The company is engaged in the business of manufacturing, purchase and sale of motor vehicles and automobile spare parts. Maruti has six plants, three located at Gurgaon, Haryana and other three located at Manesar Industrial Town, Haryana. MSIL has been responsive to the dynamic market and has been innovating their supply chain and logistics management process. The Indian Automobile Industry has been extremely competitive and will further get more competitive. Since, Maruti has very well worked on their operations research tool of logistics and supply chain there were able to overcome the problem. The Indian Automobile Industry has been extremely competitive and will further get more competitive. Continuous innovations in supply chain and logistics management will contribute positively to the overall efficiency.

In Maruti Suzuki, for the improvement in car manufacturing effective integration of suppliers is important. It has more than 800 suppliers, supplying different components thus it isexceedingly difficult to avoid delay in the process of production. Therefore, there is a need for MSIL to expand its supplier's network strategically. The operation research tool used here is supply chain to reduce the time in production because of lag time in the supplies which delays the production process and increases the overall overhead cost. Because of supply chain management Maruti has halved its man hours spent on single car and increased its productivity of dealership services by 20%.

In formula one, a single second can change the course of the entire game thus it is particularly important to find optimum time to come in, replacing the wear out tyres, prevent the over-crowding and the amount of time spent at pitstops. Allocating right crew members at the pitstop helps in reducing the time. The operation research tool used here is queueing theory, which is used to minimize the time spent at pitstops, changing tyres and to decide when and after how many laps F1 car should arrive. An efficient pitstop plays a key role in whole F1 race which help players to the time spent on refuelling, changing tyres, and overcrowding which can help to change the whole trajectory of the race. Efficient crew members at pitstop helps in giving edge over other competitors.

For an automobile company to survive in the neck throat competitive industry, profit maximization plays a very integral role which is only possible by either increasing the revenue or reducing the cost. Cost minimization can save many companies by making them debt free. Now for a capital goods company, there are many other expenses which can be saved like reduction in wastage of basic raw materials, extra transportation cost incurred because of understocking or reducing the logistics cost by selecting right sizes of containers, necessary quantity of components etc. The operation research tool used here is Mixed integer Non-Linear Programming. Other tool is Inventory Optimization to reduce waste and handle the situations of under or overstocking. Cost minimization will not only help TATA Motors but also its customers as they will get the same vehicle at a lower price which not only helps in increasing

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the revenue for the TATA Motors but also maintaining their constant cash flow which in turn helps to hold their major market share in automobile industry.

V. FINDING & ANALYSIS

The queue analysis is based on the formulation of a mathematical model that represents the process of arrival of components that join the queue, the rules by which they are allowed into service, and the time it takes to service. This encompasses the entire scope of these kind of models, which include all perceivable systems that incorporate queue characteristics. We determine whether the unit requiring service is human or not. The following performance indicators must be measured: utilization factor, percentage of workstation idle time, number of parts in system (Ls), number of parts in queue, waiting time spent in queue, waiting time spent in system, and task time. Using the stop watch time study technique, the average service time and arrival rate distribution for parts at each workstation were estimated. The service times vary depending on the materials or parts used to assemble the vehicles as well as the methods used.

Game theory is frequently used in autonomous vehicle algorithms as a core decision-making layer. Participants in the game compete with one another to protect their interests by utilizing a strategy based on the game's current outcome and their knowledge. Dynamic noncooperative games are the most used for lane-changing scenarios.Postulating a decision-making model based on a dynamic noncooperative game to investigate lane changing in an urban scenario with a congested intersection, which is accomplishedusing a model that predicts driver decision-making. To that final moment, we assume that the game's outcome can be projected if each vehicle maximizes the interaction's payoff. For two players, we presented a dynamic noncooperative decision-making model based on nonzero-sum game theory. The goal was to equip self-driving cars with the ability to analyse human decision-making processes and act accordingly.

Internal consultant analysis to understand the issue, capability development, including analytical principles, math models, and tools, and early collaborative project with stakeholders and decision-makers to scope and maximize the potential impact of implemented solutions.Prognostic algorithms estimate upcoming failures and send a notification to the driver. These analytics have already proven their worth by detecting a quality issue caused by a supplier shipping out-of-spec components. Not just to did the tool detect the problem, but it also identified which vehicles had the faulty component.

To optimize these contenting and pricing decisions, General Motors utilises operation research. As per research, if the options or selection processes are overly complex, consumers may choose to simplify or postpone decision making to reduce stress and avoid regret. Constructing a consumer choice model to capture consumer choice dynamics and solving an unconventional optimization problem embedded with a nonlinear choice model. General Motors has developed in-house capabilities to solve these extremely complex problems, which has played a role to lower design and validation costs by getting the content right early in the vehicle development process, avoiding the cost of engineering variants that customers do not want.

Target costing is an attempt to reach a predetermined cost that has been chosen by management throughout the planning and development stage of a product life cycle. This method differs from cost elimination in that it aims to minimize expenses by creating high-quality products that have lower production costs. Target costing was a concept originated in Japan, emerging around the 60s. in American terms it is also mentioned as “value engineering”, initially developed at General Electric, a concept that tends to maximize product attributes while minimizing their costs. It simply means lowering the costs of a production without compromising the quality of the product.

TATA had to face hard challenges to deliver test results validating different scenarios and executing automation. For this to overcome, tool “simulation” was use where TATA’s engine control modules would be connected to LABCAR. Also, LABCAR models are made to be a high-fidelity simulation which is an important asset for all system testing their requirements. With further and advanced ETAs tools like ETAS ASCMO-MOCA and engineering services, LABCAR-MODEL-ICE and -VVTB will well prepare the team to handle such challenges of the future.

Toyota using the Kanban processing, which is a chain process in which orders flow from one process to another, the production or delivery of components is pulled through the production line.Firstly, Toyota decides what the new retail price of the automobile is going to be by taking the old price and adding the value of any new functions. The sales division takes care of the suggested production volume, taking past numbers and indexing them to market trends and stating the

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competitors. After all this, the focus changes to cost planning. By using this technique of target costing, Toyota removes variable costs that models incur, like wages and indirect costs and then makes their decisions only based on change in design and production volume of the model. This leads to maximum utilisation of the inventory already available

The results of experiments demonstrate that both IRACE and SMAC can accelerate the solving process for each of the four issue types and surpass a straightforward random search. IRACE converges to better ultimate outcomes, even if SMAC is superior at the beginning of the parameter tweaking process. However, whatever parameters these are and what their ideal values are vary depending on the issue type. Also, testing findings show that performance tends to decline when more electric vehicles are taken into consideration. As a result, the number of electric cars taken into consideration affects the parameter setting.

To tackle the problem, a useful Lagrangian heuristic technique is designed as linear integer programming models. To evaluate the model and the solution technique, instances of varying sizes, from tiny to enormous, are created at random. Computing results demonstrate that the suggested technique can quickly and efficiently produce good answers for all examples. This method is used in automobile industry to deliver the vehicle to customers.

The total efficiency of the whole value chain will increase because of ongoing improvements in supply chain and logistics management, which will also benefit all value chain participants. All the partners have benefited from the improvements made in terms of lean operations, partner integration in the value chain, cost savings, inventory reduction, shorter transit times for finished cars and spare parts to their dealers, and meeting the constantly evolving needs of the customer. Future difficulties will necessitate even more adaptability and responsiveness from MSIL, who will also need to continuously offer innovations to further boost operational effectiveness, quality, and cost-effectiveness.

Successful and efficiently accomplished automotive simulation projects require appropriate software tools to support the client, production or manufacturing engineer, and the simulation analyst. Increased awareness of simulation capabilities up and down the supply chain. We can observe increased ease and prevalence of importing such automatically collected data into simulation models seamlessly in the automobile industry.

VI. LIMITATIONS

In the field of Operations Research:

- Game theory: the drawback of game theory is that, like most other economic models, it assumes that people are rational, self-interested, and utility-maximizing factors.
- Queuing Theory: Real-life situations are usually complex and go beyond philosophy and mathematics, which means that doubt persists no matter how accurate the data is.
- Prognostic algorithm: The concept of the system raises systematization issues.
- Mixed Integer Non-Linear Programming - The requirement to evaluate all time periods at once; the possibility of the problem being multidimensional.
- Inventory Optimization: Requires increased space to hold inventory, it is complex method, inaccuracy of data due to change in demand.
- Supply Chain: Implementation of supply chain management is sometimes expensive to businesses as it requires trained and personalized staff and lack of coordination.
- Target Costing: To control cost, the result could be usage of cheap material and technology and it might result in an excessive burden to control the cost
- Simulation: Simulation as a method could be expensive in the industry adding up to its cost. It is not precise method to use. As the number of parameters rises, it becomes harder to determine the ideal values.
- Lagrangian Heuristic Algorithm- Use of Heuristic can be difficult in way of underlying data patters, product mix etc that can represent a substantial risk to your company's overall productivity and profitability.
- Supply Chain: Processes are not organised, lack of using key performance indicator, having communication problems between various sectors, avoiding reliance on technology and wrongly predict the demand for your business
- Mixed integer linear programming: Non-linear effects cannot be considered, risk of being very dimensional.

VII. CONCLUSION

Following a quick review of the publications, it can be said that the following techniques should be used: simulation, queuing theory, prognostic algorithm, vehicle content optimization, mixed integer linear programming, lagrangian heuristic algorithm, supply chain and logistics management, mixed integer non-linear programming, inventory optimization and target

costing. As we see that the automobile industry, that it is declining in the Indian Market, making it necessary for the companies to study and work in maximizing the profitability of their products or services. This research paper provides insightful information on the various facets to achieve the same. There are other various models that can be used but, models used by our team in this research are the most effective.

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