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Application of Operations Research in Cab Aggregator Route Assignments

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Abstract:- The paper aims to provide information about the Cab Aggregator industry in India and establish a link between the route optimization of cab aggregators with various concepts of Operations Research. It also provides an insight into the current status of the Indian Cab Industry. In addition to this with the help of past studies it aims to analyse past and present processes used to assign routes and offers its own analysis on how companies can optimize assignments effectively.

I. INTRODUCTION

A rapid and significant evolution can be seen in the field of urban transportation. In recent years, the advancement in the field of Internet and improved smart-phone technologies has made us increasingly connected with each other because of which we are able to plan and optimize our daily commute. Online booking of taxis has become an integral part of the urban lifestyle, with it being preferred over traditional transportation methods as it offers value for money, saves time and for its ease of use. The vast amount of growth in this sector is a testament to the rising dependency of people on cab aggregators. In spite of their late entry into the market, cab aggregators like Ola, Uber amongst others have been able to establish a stronghold in the market, with cab aggregators posting a higher rider ownership than traditional cab owners and affiliators like Meru cabs, Easy cabs, and Savaari etc.

A major aspect contributing to their success has been their efficiency and ability to innovate. To improve the efficiency of their transportation systems large amounts of data is gathered and analysed to improve their operations. Today, innovative systems like car-pooling are built, and a centrally controlled transportation structure is used by real time ridesharing companies like Ola and Uber to revolutionize the taxi industry.(Redseer, 2014)

The main motive of cab aggregators is to satisfy passengers' personalized requirements and provide passengers with convenient and comfortable trips. In order to improve operational efficiency of taxis, it is essential to encourage the wide spread of ride-sharing services. Careful organization, optimal scheduling and reliable management are needed for effective ride services.

Vehicle routing of cabs, to ensure maximization of efficiency and customer satisfaction and minimization of time and associated costs is one of the most crucial aspects of the entire route assignment system. For this, a Demand Responsive Transit System (DRT) is used. It refers to an advanced user-oriented form of transportation system which is characterized by flexible route assignment and scheduling of vehicles between the pick-up and drop off points to cater to the passenger needs accordingly. The minimization of operating cost and the maximization of customer satisfaction is the main objective of this model. (Li)

Operations Research refers to the application of scientific and mathematical methods to study complex problems. In a nutshell, it is a systematic process of applying advanced analytical methods to a particular problem in order to make better and more informed decisions.

As far as the Cab Aggregator industry is concerned, OR can be extremely helpful in improving vehicle routing efficiency, and can have a major positive impact in improving the efficiency of operations. In the field of route scheduling, optimization of each vehicle can be actioned to maximize the system efficiency throughout, with OR being used to decide which taxi should be assigned to which route so that time and cost are minimized. This will ensure that the passengers personalized requirements are satisfied and comfortable, convenient and prompt trips can be executed.

II. INDUSTRY OVERVIEW

The taxi market in India is highly fragmented and unorganized, with the unorganized sector consisting of individual car owners and companies existing in one or two cities, with the organized sector comprising of owners like Easy Cabs, affiliates like Savaari and cab aggregators like Ola and Uber.

The online taxi market has grown at a phenomenal rate of 250 % from 2016 to 2017, with the growth mainly driven by cab aggregator companies. However, the cab aggregation industry is still considered to be a budding industry, with a major portion of ridership belonging to the unorganized sector. The growth is expected to increase 30 percent every month and this substantiates the huge potential yet to be tapped in the market. The rise of the Cab aggregation industry not only solved the problem from customer perspective but also helped the drivers in making their earnings better. In addition it also attracted many young Entrepreneurs getting into this space slowly, in a way it almost became a kind of practice that one in two young entrepreneurs are thinking of trying their luck in this space. Ola and Uber became more popular and are able to capture the market share with the help of technology and their innovative business models. However as similar to any other industry, there is a fierce competition amongst the companies which reached a certain high point and are trying all possible strategies at the moment to sustain their position. Also people are coming up with new ways to facilitate the customers, innovating aggregation mobile apps for cab aggregators, with which a user can search from all available aggregators. Oye taxi and scoot are examples for

such unified aggregator apps. (Mr. Sai Kalyan Kumar Sarvepalli, 2016)

Given that our research paper primarily focuses on the Taxi Aggregator Industry, it only makes sense that we handpick the two main players of the industry: OLA & UBER, in order to get a thorough understanding of the overview of the entire industry. As established, OLA & UBER are the two major players in the industry, together holding roughly 95% of the market for cab aggregators, effectively establishing itself as a Duopoly. However, circa 2018, it's becoming increasingly clear that OLA is pacing ahead by a large margin. Stats show that by early 2018, OLA has been operating in 110 cities compared to UBER's paltry 31, giving the home grown business a significant boost in targeting a massive customer base. (Bhattacharya, 2018)

While OLA has been witnessing growth trends since mid-2017 with a hike of 3% in the market share from 53% to 56%, as per market intel sources, UBER has also seen a share change of 3%, albeit of a downward nature with its share dipping from 42% to 39%. Speaking of market shares, it must also be noted that the Industry also has a few other players like MERU CABS, JUGNOO & IXIGO, though their collective share is a mere 5%. Given OLA's dominance in regards to market share, it's really no surprise that it also commands a massive fleet of a million drivers as compared to UBER, which commands a number of about 4.5 Lacs. OLA also surpasses UBER in terms of application installations and in a survey by Kala Gato, OLA emerged victorious with 40% users reporting that they used the app more frequently than UBER which was reportedly used by 28.7% of the people. The survey also happened to mention that UBER has a higher uninstall rate as compared to OLA.(Bhattacharya, 2018)

The cab aggregator industry is characterized by heavy competition to gain a greater market share, and thus has seen several innovations maintaining the dynamic and ever-changing nature of the industry. Some of the developments include the launch of the Pre-Booking option by Ola, allowing users to carry out advance booking of their cabs. Location tracking services, Trip sharing and SOS features have all been introduced over the years to cater to customer needs and enhance personal satisfaction and safety. Contributing to its ease of use has also been the apps and various payment methods on offer, with the cab aggregators accepting payments in cash, e-wallets and even through credit cards.

The Indian cab aggregator market is still in its nascent stage, as it suffers from operational issues like poor public infrastructure and poor car penetration level. However, the growth of the industry has been impressive as strong customer demand ensures the Indian market is poised to grow in double digits over the next 2-3 years.

III. LITERATURE REVIEW

The process of optimal route allocation poses a lot of challenges and problems, with some of them being deciding the shortest route, assigning drivers to different ride requests, adjusting the travel route according to dynamic variables like time, traffic etc. In order to attempt to decide the most optimal method to route based allocation, it is necessary to understand the past methods that have been used for the same. The urban centres of the world are getting oversaturated as more and more population moves to large cities looking for higher standard of living. While demand for mobility increases, supply of roads is limited and thus needs to be optimised in a cost-efficient manner. In order to increase efficiency many models have been tried and applied in the past such as

- *Aggregated models*

Multiple studies were conducted with the precursor being Douglas (1972). These were based on assumptions such as a market where hailing cabs on the street was the only method of engaging a trip and prices were regulated. He concluded that the maximum revenue to the industry occurs at the point where demand is less than maximum, characterizing social welfare as an efficient but unfeasible (deficit) equilibrium. This study was used as a reference to further conduct studies under different assumptions such as De Vany (1965) where different markets such as monopolies and free market were analysed.

- *Equilibrium models*

These models were extensively focused on price and entry controls of the markets, basing the study on aggregate demand and supply in different markets (monopolistic and competitive). Certain assumptions are the relation between the waiting time and the total number of vacant taxi hours, constant operating cost per hour and demand estimation based in fares and waiting time of passengers. These models include the study of Manski and Wright (1976). In equilibrium model information was a critical factor in assessing the efficiency of cab services. The knowledge and experience of individual taxi owners was used as a parameter with the assumption that more experienced drivers will find rides faster. A smaller fleet of informed taxis could be better for both customer and drivers, the conclusion drawn was regulation was required on taxi fleets and information for optimal utilisation of resources.

From the above information, it can be concluded that with time the models are becoming complex and realistic. Beginning from aggregate models which ignored market conditions, later models included multi-dimensional constraints regarding market conditions and driver experience. (Josep Maria Salanova, 2011)

➢ *Development of Techniques used by Cab Aggregators*

It is possible to classify a taxi service in four ways, according to the presence or absence of information about geographical locations of taxis and passengers(Reis, 2011).

The first one, is a "Random searching" mode method, which is used when the passenger is waiting in a random location for taxis moving around in trans it (AbilioA.M.deOliveira, 2015). This circumstance is portrayed by the ignorance of places of both, cabs and clients.

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The second mode, "Fixed stop", happens when customers pursue a taxi point (AbilioA.M.deOliveira, 2015). It is described by the knowledge of taxi positions, anyway the customer's underlying position is obscure.

The third mode is the "Broadcasting"; however, the places of taxis is obscure by the central control system(AbilioA.M.deOliveira, 2015). In an example of this mode, a passenger calls the central services and the location of passenger is passed on by radio to taxi drivers. The first driver to acknowledge the demand is confirmed by the central system to get the passenger(AbilioA.M.deOliveira, 2015). Since the position data of the available taxis is obscure, this strategy does not ensure that the nearest driver or the most optimal vehicle is assigned to the passenger (AbilioA.M.deOliveira, 2015).

One of the methods to classify a taxi service is "GPS – based models", which can distinguish the geological position of both, clients and cabs(AbilioA.M.deOliveira, 2015). Algorithms used to define the taxi driver which will be on charge for picking up every passenger are used to differentiate these GPS methods from each another. The criteria and costs used by the algorithms to choose the attendant to each request is determined by the geographic allocation of the actors involved(AbilioA.M.deOliveira, 2015). The difficulty of a taxi driver to answer a call is determined by the cost. Basically, there are two methods that can be used: the Euclidean distance and the routing distance between each customer and the available vehicles (the distance that each taxi driver has to travel through roads and streets before reaching the customer)(AbilioA.M.deOliveira, 2015).

The following is a brief review of the research paper "automatic optimal taxicab mobile location based dispatching system": (Myr, 2011)

Latest technological developments have allowed for better dispatching methods enabling the taxicab business owners to maximize their profits whilst simultaneously reducing costs and enhancing customer experiences. As such, whilst determining how to maximize profits, the taxicab aggregators are also subject to some restrictive conditions like times, quantity, designated locations and forwarding locations. Another factor to be considered are the transportation costs with high fuel prices one of the most important factors. As we've learnt in class whilst learning Transportation Problems, it may so happen that the aggregator may have all his cabs engaged and no cab is available for service, and in such a case, the customer has no alternative other than to wait. There is a need for improving the method for performing the optimal vehicle dispatching using modern communication ways and the use of satellites. The paper goes onto mention several authors and their suggestions on how to better optimize the dispatching systems which we will also be referring below:

Nobutoshi Umeda's contribution in US Patent 20060034201 "Taxi dispatching system and dispatching method" is mentioned and it goes at length about a system by the way of which a customer can request for a cab using a phone, following which a central system accepts the request and then authenticates the cell number and sends an email to the customer who then chooses the dispatch conditions which are assigned to multiple taxi drivers. The central system then selects the optimal taxi based on bids from taxi drivers satisfying the conditions. (Nobotushi Umeda, 2004). The research paper also details the contribution of H. Lee in US Patent 7528715 "Method for Optimal Multi-Vehicle Dispatch and System for the same", mentioning that a vehicle dispatching system enabling multiple dispatches with information of available vehicles from the vehicle aggregator and details of orders from client devices under restricted conditions such as vehicle size, minimum loading rates, maximum number of assignment places taking into account transportation times, past orders in order to minimize a total transportation cost for each region. (Lee, 2006)

IV. OBJECTIVES

India seems to be going through a probable Taxi revolution. Despite the growing use of operations research in taxi aggregators, this area of research lacks extensive studies. The main purpose of this work is to identify the solution in which all current customers are met in an optimal time, however minimizing the distance travelled by existing free taxi cabs. The various objectives of the paper include

- Presenting an overview of the Indian Cab Aggregator Industry
- Analysing various Operations Research Methods used for optimal allocation of cab route assignments.
- Attempting to develop further ways through which the industry can utilize the science of Operations Research
- To educate the readers about the use of Operations Research in the Cab Aggregator Industry

V. METHODOLOGY

For the purpose of this research paper, data from secondary sources such as existing research papers, Websites, Articles have been used with the aim of analysis.

Assignment Problem has been used to determine how Cab companies can ensure route optimization. Simulation has also been used to just how cab aggregators can estimate demands for their fleet.

VI. ANALYSIS

In this paper we'll study the role operation research plays in the taxi aggregator business. Consumers now want convenience of travel as well as the cheapest mode available when choosing a cab. From the side of the cab aggregators, they would like to assign cabs to each ride request in such a manner which minimizes time as well maximizes profit on each ride completed.

In order to understand the problem and optimize it, it is necessary to understand the cab booking process. The users first make a request for the cab through the cab aggregator app, providing details like pick up and drop off location. The cab aggregator, on a real time basis assigns a

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cab to the customer based upon factors such as vicinity to pick up location, driver discretion etc.

In order to provide maximum profit on each ride to the cab company, we have used the example of an assignment problem to allocate different cabs to different rider requests. Various factors such as cost of travel and time taken to complete each ride have been quantified for this purpose.

For the purpose of analysis, consider a Cab Company Yellow Cabs Ltd. The company is in the business of providing cab services, thus transporting people from one place to another for a fee. It gets requests from various customers when they make their bookings with the company, which is then followed by assignment of a particular cab to each customer.

For simple understanding the following assumptions have been made:

- The cab company has a total fleet of 3 vehicles.
- Total ride requests at a particular point of time by the customers is 3
- Total Cost per ride = Distance Travelled x Cost/Km + Total Ride Duration x Time Rate

The following model deals with a situation where 3 riders at different places in the city have requested cabs and the company now has to assign each available cab to a rider in a manner which minimizes cost of each ride to the company. The riders are located at different locations in the city and have made a request for a cab to the company. The cost per ride incurred by each cab varies depending on the location of the rider and the destination and total cost of each route is denoted as C1, C2, and C3 etc.

The following matrix depicts the problem at hand

Vehicles Available/Rider Requests	Location 1/ Rider 1	Location 2/ Rider 2	Location 3/ Rider 3
Cab 1	C1	C2	C3
Cab 2	C4	C5	C6
Cab 3			
Cab 4			

➢ *Steps in solving the AP*

- The first step is to balance the problem. An assignment problem is said to be balanced when the number of rows is equal to the number of columns. In this case the number of cabs available with the company should be equal to the number of trip requests. If the problem is not balanced, it is made balanced by as many dummy rows/columns.
- The second step involves getting zeroes in every row of the matrix (Finding the Row Minima). For this, the least value in every row is subtracted from each row element. In the above problem, taking the case of Cab 1, the row shows the cost per ride incurred if Cab 1 transports Rider 1 i.e. C1, cost if Cab 1 transports Rider 2 i.e. C2 and so on. Thus, the least cost incurred is taken and subtracted from all the other costs in the row. This step is repeated for all rows.
- The third step involves getting zeroes in each column as well, with the same method as above being followed. With respect to the case, costs would be analysed with respect to one specific rider availing the ride through all the potential cabs. Thus when solving for Column Minima, cost per ride if the Rider travels through Cab 1,Cab 2 and Cab 3 respectively would be analysed.
- After obtaining the zeroes, allocation is made to each row which will have a single zero. All other zeroes in the column will be cancelled. This step is repeated for each row till all the rows have a single allocation.
- However, there may arise a situation when the number of allocations is not equal to the order of the Assignment problem, which indicates that the solution is not optimal. In order to make the solution optimal, the tick method can be used to optimize the problem.

After solving the Assignment Problem, the following matrix will be achieved. The highlighted box shows the assignment of each cab to a specific location, which ensures that the total cost is minimized during the daily operations of the company.

Vehicles Available/Rider Requests	Location 1/ Rider 1	Location 2/ Rider 2	Location 3/ Rider 3
Cab 1	C1	C2	C3
Cab 2	C4	C5	C6
Cab 3	C7	C8	C9

➢ *Process in case cabs are unavailable*

During the operations, there may also arise situations when one particular cab is unable to perform a particular trip. This can be due to various factors such a car failure, traffic jams in a particular route etc. In order to tackle this problem, we can take the help of prohibited assignments.

For example, if on a particular day Cab 2 cannot reach Location 1, then that transportation route can be blocked with a very large value M, replacing the cost value. This will ensure that the route is not selected and the problem can be solved as usual.

Thus, by using the above model, Yellow Cabs will be able to assign each cab available to each rider request in such a manner that when the ride is completed, the cost incurred is minimum to the company. This will ensure that on each ride completed, the company earns maximum profit. The model will allow the company to analyse the various costs available and it will scientifically be able to select the best possible method,

Thus, in the above case, Assignment Problem has been used to ensure optimal assignment of resources to the given tasks, thereby ensuring efficiency of operations. This is beneficial that simply assigning cabs based on single variable like distance or time, as this considers minimization of each trip cost to the company.

A cab service finds that there has been a massive discrepancy during the past few months in the usage of its fleet of cars and as such that the servicing costs have also

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fluctuated. The following data highlights the demand for the cabs over the course of several hundred days:

Rides per week	0	1	2	3	4	5
Frequency of rides happening	16	24	30	60	40	30

We shall make use of the following random numbers to simulate demand for an 8-week period:
81, 97, 13, 53, 12, 23, 58, 19.

Before we start with Monte Carlo Simulation, it's essential that we calculate probabilities of rider per week.

Rides	Frequency	Probability
0	14	17/200 = 0.07
1	26	26/200 = 0.13
2	28	28/200 = 0.14
3	62	62/200 = 0.31
4	36	36/200 = 0.18
5	34	34/200 = 0.17

Total of Frequency=200.

Rides	Probability	Cumulative Probability	Random Number Interval
0	0.07	0.07	00 – 06
1	0.13	0.2	07 – 19
2	0.14	0.34	20 – 33
3	0.31	0.65	34 – 64
4	0.18	0.83	65 – 82
5	0.17	1	83 – 99

Simulation Worksheet:

Day	Random Number	Rides
1	81	4
2	97	5
3	13	1
4	53	3
5	12	1
6	58	3
7	19	1

With the help of this data that we have calculated via the use of Monte Carlo Simulation, we can advise the cab service on its servicing cost expenses and how to best minimize them. We do this by calculating the Average Demand for the cabs:

18/8= 2.25

With the help of this information, the cab service can decide how to go about its servicing and maintenance expenses on the basis number of cabs in demand.

VII. CONCLUSION

The paper has attempted to cover the taxi aggregation industry in India and how cab aggregators use innovative methods for route optimization. It also provided information about the current status of the industry, enlightens the users about various market players, growth rate etc. The success of the taxi aggregator business model is ample proof of the ever growing influence of technology in the success of a business. Technology has played a greater role in effective alignment of demand and supply in taxi aggregator services. This paper highlighted the innovative manner in which the aggregators like Ola and Uber have penetrated the Indian market using smart phone technology. They have identified the problems in urban transportation in Indian metros and then converted them into business opportunities. What is more, they have achieved success in their efforts too. Research on service supply chains is still evolving. The peculiar nature of services adds to the complexity in service delivery. However technology can be a great enabler in service quality. Having achieved success, the taxi aggregators need to focus on performance measures to ensure the sustainability of the business model. With increase in the levels of the service quality, the expectations of customers are bound to grow in the future. Performance metrics enable benchmarking of the services and direct the focus on continuous improvement in service quality. Taxi aggregators should also focus on innovations to grow the business. Briefly it also provided its own contribution on how the Cab companies can improve efficiency in route allocation by way of an Assignment Problem example.

VIII. LIMITATIONS

In spite of advancements in technology and use of operations research to ensure efficiency, there can be a variety of factors which can adversely affect the route assignment operations of cab aggregators. These issues can originate both from the shortcomings of the Aggregator or the customers and can also be due to some unavoidable circumstances:-

- Lack of availability of idle cabs.
- Undesired events like strikes, route unavailability etc.
- Surge pricing
- Service Rejections and Driver Denials

Some other limitations encountered during the research process were:

- Lack of primary data about the cost structure of cab aggregators
- Lack of expertise about Operations Research methods

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