Matching and Market Design in Car Hailing Market

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Abstract—Online ride-hailing plays an important part in our lives. Until recently DIDI already have about 493 million active annual users. [1] As the pace of life becomes faster, people are also pursuing more efficiency. An increasing number of people are capable to use advanced network technology to call cars to achieve true peer-to-peer commuting. Making the entire taxi system more efficient is not only for passengers to save time and cost, but also for drivers to increase their productivity. In this essay, five different two-sided matching models will be compared to discuss the current research progress, development trends and shortcomings of online car-hailing platforms. Besides, three criteria will also be mentioned in this essay in order to measure effectiveness of different algorithms. After the research, it shows that batch matching and serial dispatch are two optimal choices. If these two algorithms combined with the dynamic vehicle routing problem (DVRP) may provide higher efficiency for passengers, drivers and the car-hailing platform. Further researches about DVRP and data analysis are needed to provide a solution to the problem in the online car supply market.

Key words: matching, online car supply, market design, dynamic vehicle routing problem

1. INTRODUCTION

Online car-hailing is an emerging transportation method in the world. There are over 30 million [2] orders are created per day. This enormous figure represents the significance of the allocation of resources in the online car supply market. The creation of a two-sided matching mechanism in this market is to benefit the drivers and passengers not only by achieving Pareto efficiency but also stables the market and being strategy proof. For online car-hailing platforms the demand for cars substantially increased during peak hours. It is difficult for people to hail a car during rush hours. Under the crowded circumstance with excessive demand for cars, four different mechanisms will be compared and evaluated in this essay and the main goal is to list

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the positive and negative sides while trying to use the theory of two-sided matching theory to reducing the waiting time for both passengers and drivers and increase the utilization of the resources in order to maximize the efficiency.

2. MATCHING MECHANISM

To design a mechanism and let the algorithm become feasible, they need to provide thickness, make it safe and overcome the issue that the sickness can bring [3]. The thickness means that design a market needs a sufficient amount of data. Safety implicates that the people in the mechanism are willing to the disclose the truth that they know which is another way to be strategy proof. Measures are also needed to be made in order to surmount those congestions caused by the huge database and provide the best choice when there are other alternatives.

In all matching mechanisms, three factors are vital which is efficiency, stability and strategy proof. At the same time, these three points will also become an indispensable part of measuring the advantages and disadvantages of different algorithms. [4]

Two different objectives will be mentioned in the following mechanisms, driver-centric and passenger-centric. The driver-centric objective is to maximize the productivity of the drivers on the platform and their salaries. The passenger-centric objective is to minimize the average pickup distance of all the assigned orders. [5]

2.1 Enumeration

The enumeration method is the most primitive method. It enumerates all the drivers and passengers in a certain region, and then calculates the optimal choice for each group of drivers and passengers. It can simply and effectively help drivers and passengers find the combination which has the shortest waiting time. This method can easily reach a stable matching since telling the true destination and requirements is the optimal choice for every user, both drivers and passengers. Thus, this mechanism is strategy-proof. In addition to that, this method also has the highest efficiency because every people only wait for the minimum time.

However, even if the enumeration method reached all three essential factors that the author has mentioned before, many big car-hailing companies have chosen not to use these methods. This is because the computers are not capable of handling so much data during peak hours. Thousands of orders are appearing every second which is difficult for the platform that only has access to limited computing power. With the tremendous amount of calculation, there will be minutes of delay, even hours which will directly lead to an inefficient two-sided mechanism.

2.2 The principle of proximity

This is a passenger-centric algorithm which is to simply allocate the nearest driver to the passenger which is the most reliable and practical one. Up to 90% of the orders are using this method because it has simple and reliable features. It does not need to rely too much on the computing power compared to the enumeration method.

Nevertheless, there still exist some problems with this algorithm. The online car supply market is a market with dynamic demand, as orders for a taxi will continue to appear. This may directly lead to some problems like longer waiting time in total for the platform. From a macro perspective, this algorithm may lead to an increase in the total waiting time and this will be discussed thoroughly in 3

2.3 Batch matching

This algorithm is widely used by Didi, Uber, Lyft and other online car-hailing services. Thanks to it capability of collecting user's need within a short period, and then performs unified processing, this algorithm can reduce the overall time while minimizing the waiting time of almost all passengers. Although this is a globally optimal option, it may cause some delays for some customers. In addition to that the global optimization may lead to postponement of receiving for drivers. The delayed time is used to wait for data collection to be completed and processed those the computers. Thus, ensure the shortest total time for the whole platform, a long process is inevitable collateral.

There are still some shortcomings and deficiencies in this algorithm, such as the uncertainty of the length of time of collecting data, and the inability to make a corresponding response to the changes in the dynamic market, whether to accept an incoming request and etc. Real-time mode hardly makes sure the efficiency of assignment because better matching objects often appear after the allocation. [6]

2.4 Serial dispatch

This is a driver-centric algorithm. The algorithm assigns surrounding orders to drivers who are about to end the service and are close to the departure place of passengers who want to get on a taxi. Since there are almost no idle drivers on the platform during peak periods, most unoccupied drivers are converted after completing orders. In order to maximize sales and improve efficiency, serial dispatch has become the optimal solution. This algorithm calculates the optimal options for the driver by monitoring the driver's destination and the passenger's departure point and sends it to the driver's mobile phone for them to choose in a period of time. This can effectively compress the order responding time and minimize the time for drivers which is wasted on traveling from the current location to the passenger.

Despite the algorithm provide a much convenient way for drivers to get an order, there still exist some flaws. For example, some platforms may set an extremely short responding time. When drivers accidentally touch the screen and accept an order, there are only 10 to 15 seconds for them to confirm the order or to cancel the order without liability. If it exceeds the limit, it may deduct credit points or directly affect the salary of the drivers. However, in real life when the driver is driving at a high speed, there is no way to safely operate their mobile phones, drivers had to take orders in order to ensure safety. Therefore, some drivers who do not want to be underrated or get a pay cut, have to accept the order and continue to send passengers to the destination even if they may have already get off work.

3. COMPARISON OF TWO MECHANISMS AND DYNAMIC VRP (VEHICLE ROUTING PROBLEM)

In figure one the platform is using the principle of proximity which is searching for the closest. (mentioned in 2.2) in figure two the platform is using the batch matching method. Assuming there are only two passengers and two drivers in this region, the matching of car-hailing with two different methods will be compared in order to analyze the merits and shortcomings in the two approaches.

If the proximity principle is adopted under this situation, the computer will provide a solution as shown in figure 1. Because of the characteristics of the principle of proximity (first come first served), passenger 1 is paired with vehicle 1 and there are only two minutes of waiting time which is comparatively short. When passenger 2 orders a car later, vehicle 2 is the only available car in this area, so passenger 2 lacks of choice. She has to wait for 9 minutes. The advantage is that passengers can get a response from the driver immediately, but the disadvantage is that the waiting time between the two is too different, resulting in a total time of 11 minutes.

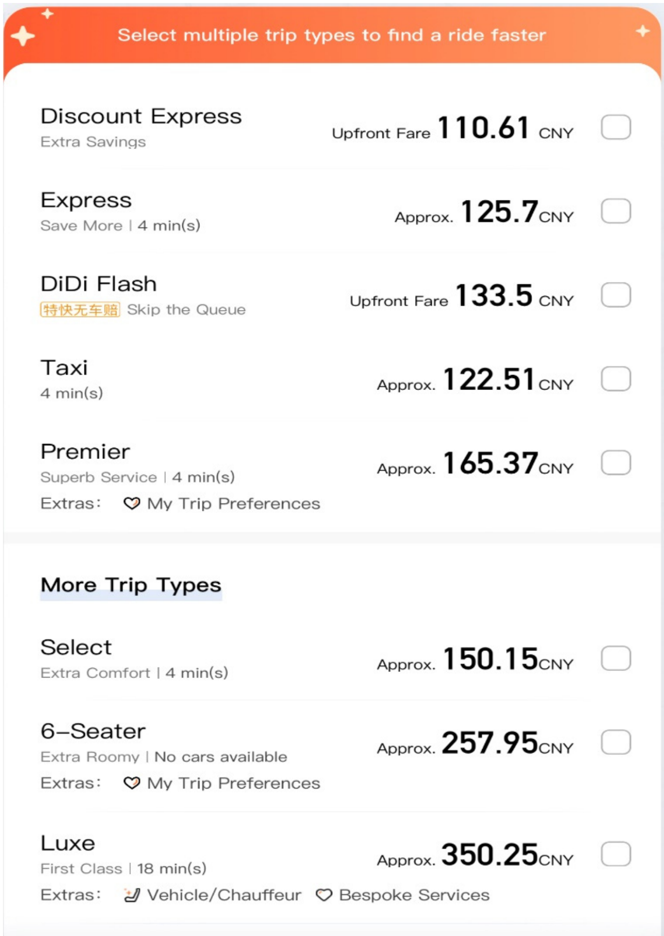

Figure 1 Screen shot from didi app

If the batch method is adopted under this situation, the computer will provide a solution as shown in figure 2. After using the batching method, once the information is collected in a certain period of time, then the mechanism will allocate passenger 1 to vehicle 2 and it has a waiting time of 4 minutes. The remaining one car and one person are naturally paired, and their estimated time of arrival (ETA) is also 4 minutes. It seems like passenger one is worse off because he has to wait for other minutes. Passenger 2 has undoubtedly benefited, and her

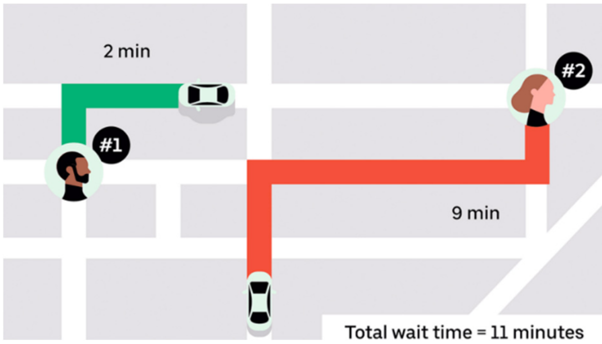

Figure 2 principle of proximity [7]

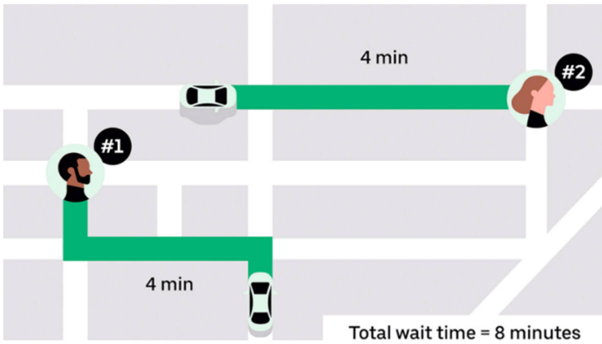

Figure 3 batch matching [7]

waiting time has been reduced by 5 minutes. This method may not be the optimal choice for some of the passenger, but it shrinks down the total waiting time to 8 minutes. After the comparison, the first method has a faster response speed. But thanks to a shorter overall time, the batching algorithm is considered by DIDI, Uber and other online ride-hailing companies to be the global optimal algorithm. Although batch matching has been adopted by many major companies for various reasons mentioned above, the algorithm still has its drawbacks, such as the inability to apply dynamic changes in the market to the matching mechanism and etc.

Dynamic vehicle routing problem (DVRP) is to plan the vehicle path based on the known information, receives dynamic information such as different demand from the passenger and traffic congestion in real time during the implementation process, and re-plans the previous route according to certain rules to achieve the goals required by the system.[8] The dynamically changing data is revealed during the design or implementation of a statically planned solution.[9]

DVRP in the online car-hailing services acts as an important role. It can help this platform to calculate the passenger's dynamic demand and location, combined with the actual driver's GPS positioning, can calculate the best matching result.

For example, when one person wants to travel from his home to the Shanghai HongQiao airport, there will be plenty of choices, as DIDI offers variety of options of cars such as express, DIDI flash, taxi, primer and etc, in order to distinguish itself from Uber[10],(showed on the figure 3) for just choosing a car model. Different people may choose to different type of cars. Then this kind of personalized needs cannot be solved by the conventional algorithm because it cannot handle the dynamic change in the market. Inserting the DVRP into the existing algorithms might be an optimal choice to meet the demand of consumers and maximize the efficiency of the platform.

4. CONCLUSION

With the increasing demand for online car-hailing, travel efficiency has become particularly important. The abnormal delay when calling a car may be caused by the wrong and inefficient matching mechanism. The paper gives several efficient matching algorithms, enumeration, the principle of proximity, batch matching, serial dispatch and dynamic vehicle routing problem. In these algorithms, the author believes that batch matching is the best choice for platform because of the special model of processing the data which enables the platform to allocate drivers to passengers with shortest total time. For drivers, serial dispatch can help them improve their efficiency. The shortcomings of these two algorithms, that is, the lack of processing dynamic information on the market which can be greatly reduced through the study of DVRP.

In future research, the author believes that collecting more data, such as different user preferences and trip data, will help taxi-hailing platforms better handle dynamically changing data, thereby improving driver productivity and reducing passengers' waiting time. At the same time, further research on DVRP can ameliorate the defects of the algorithm and process dynamic information with more efficiency.

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