Evaluating the Effect of Switching Taxi Demand into Ridesharing Mode: A Case Study in Chicago

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Abstract

The rapidly expanded urban landscapes lead to an escalation of traffic congestion and its consequences in terms of overall delay experienced by travelers. Ridesharing emerges as a sustainable and practical method to reduce traffic congestion in urban areas. This paper analyzes and quantifies the macroscopic effects of converting a sizeable portion of taxi rides from conventional direct point-to-point service into a ridesharing modality in a large metropolitan area, using an available large set of taxi trips from Chicago. We simulate and evaluate the pros and cons of various scenarios of ridesharing modalities, starting with a pairing mode, with maximum of two passengers, up to a full ridesharing mode, with four passengers per vehicle. In particular, we aim to maximize the reduction of total driven miles, yet ensure an acceptable level of service to passengers by imposing a maximum additional waiting time of 15 minutes and a journey time increased by half compared to the traditional cab rides. Results show up to more than 50% less total driven miles with only an average of about 11% extra time on vehicle per passenger. Sensitivity analyses are conducted to evaluate the effect of ridesharing capacity and service levels with expected yet now quantified trends. The following actions ordered by effectiveness will positively influence the total mileage savings: 1) increase the maximum number of passengers matched together to one vehicle, 2) Increase acceptance of an extra time in relation to the travel time, 3) Increase the waiting time availability of other passengers for ridesharing. The experiment aims to provide tools and detailed information for planners and policymakers to intervene by incentivizing a conversion, even if partial, of the taxi services into ridesharing service, presenting an opportunity to improve traffic conditions and the overall efficiency of the transportation system.

Keywords: *Large Urban Areas, Ridesharing, Mileage Saving, Travel Quality, Vehicle Occupancy*

1. Introduction

The escalation of traffic congestion and low traffic efficiency problems urge transportation planners to propose corresponding solutions. One of the effective and economical methods is ridesharing (1), which happens when the following conditions are met: travelers agree to share vehicle space and travel costs with others, passengers have similar time and route schedules, and drivers of private vehicles agree to join ridesharing plans. Ridesharing fully utilizes vehicle capacity by grouping those feasible travelers, so that the number of private vehicles may dramatically decrease, especially in urban areas during peak hours. Since private vehicles are a major source of fuel consumption and air pollution, ridesharing is beneficial in reducing the effects of high gas price problems and environmental concerns. However, the private car occupancy rate is still relatively low, based on the report from the Federal Highway Administration (2). The average vehicle occupancy in the U.S. is about 1.67, which means a substantial proportion of seats is empty when we assume that four seats are on per private vehicle. Low vehicle occupancy indicates more vehicles on the road network to satisfy travelers' requirements, so the appropriate application of ridesharing to the transportation system is necessary.

Recently, more studies have investigated the impacts of the ridesharing system, showing a higher chance that the ridesharing system will be widely applied in the future. The ridesharing system considers the interactions between drivers, riders, and system managers (3). This system intends to optimize the matching problem by minimizing the difference between expected and actual departed time. The factors related to dynamics and empty seat allocation should be highly considered. One study investigated the potential opportunities and challenges for dynamic ridesharing in California (4). Statistics results showed that about 20% of commuters (employees at the University of California, Berkeley) who drive to the campus alone would like to be matched with those who have similar trip schedules. Also, many often drive to campus because of no awareness of current rideshare services. Another study investigates how dynamic ridesharing reduces vehicle miles traveled (VMT) (5). Three scenarios named business-as-usual, transit-oriented development, and auto pricing scenarios with different levels of ridesharing participation levels are studied and analysis results indicate that VMT would be largely reduced with medium (9% in transit-oriented development, and auto pricing scenarios) and high participation ridesharing levels. The popularity of smartphones and traveling apps activates the market survey of ridesharing (6, 7). Other transit modes are compared with ridesharing systems and case studies show the competitiveness of ridesharing. Ridesharing may also be limited by factors, such as demographics and land use, but ridesharing travel demand has increased after the introduction of Uber.

More existing studies focus on passengers' willingness and the popularity of ridesharing systems but do not investigate deeper into vehicle occupancy. This study intends to apply a ridesharing algorithm to investigate the potential improvements in vehicle occupancy by the ridesharing system. Several scenarios will be conducted and compared.

This paper is organized as follows. The literature review gives an overview of the development and application of ridesharing. The next section introduces the distributions of travel demand from spatial and temporal perspectives. The following section is the main part, methodology, including forming the ridesharing idea with up to four riders per cab, the ridesharing model, and the logic of inserting more riders into existing passenger pairs. Then, the simulation results of several scenarios will be compared and analyzed. Lastly, the conclusion of this paper will be summarized and some suggestions for related future studies will be proposed.

2. Literature Review

Before the appearance of dynamic ridesharing, conventional ridesharing servers, such as train stations, provide travelers with pick-up and drop-off locations. The Routing schedule is simple for ridesharing servers because of existing routes and fixed fees for customers. However, traditional ridesharing systems cannot satisfy current travelers' demands because of their flexible time schedules and locations. Also, previous ridesharing approaches are not appropriate for long-distance travel, so methods to accommodate travel demands with more flexibility need to be applied to match traffic demand (8). Based on the above circumstances, the concept of ridesharing was proposed with more flexibility for customers and drivers. The most distinctive advantage of dynamic ridesharing is matching rides quickly at any random time to satisfy travel demand, compared to the matching process of traditional ridesharing.

Recent studies on dynamic ridesharing systems (9) showed that they own the following features: dynamic (ranging from minutes to hours), independent (ride providers are independent private entities), cost-sharing (reducing cost for riders by cost-allocating), non-recurring (single, non-recurring trips, not requiring long-term commitment among riders), prearranged (riders agree to share a ride in advance), automated matching (providing a platform for riders and drivers to match suitably). Dynamic ridesharing systems could also provide environmental benefits. The number of large-scale trips decreases because grouping feasible travelers increases the capacity of vehicles, conducted by optimization methods and technologies. Thus, the total number of trips decreases, and traffic congestion issues would also be improved when ridesharing is implemented in large-scale networks with high trip density (1).

One scenario of dynamic ridesharing is about a single driver and multiple riders. A driver who has enough time flexibility provides rides to at least two riders who may have different pickup and drop-off locations. Drivers and riders are dynamically at various locations in a time process, which indicates uncertainties within the dynamic ridesharing system. Therefore, a widely reasonable and acceptable solution should be formulated. The general objective of this case is to assign riders to drivers and construct a route with minimum traveling cost (including traveling distance and time cost) for drivers and riders after matching (9). Based on the objective, the factors that were taken into consideration are similar, when constructing constraints into models. Carvo et al. (10) studied the change in travel time of system-wide with different ratios between drivers and riders. For drivers' preference, some aspects may be considered: a maximum deviation from the direct trip duration, maximum riders at a time, and maximum stops for a one-time trip. Paquette et al. (11) measured the passenger service quality concerning the difference between actual and desired driving time, waiting time, and the number of stops. Also, ridesharing strategies increase the occupancy rate (12) and decrease the total number of vehicles and traveled miles (13), which benefits the transportation network system. Furthermore, ridesharing methods control customers' travel time and potential discomfort when sharing space with unknown passengers (14).

The main ideas of ridesharing, reducing useless trips and improving vehicle occupancy rate, have been adopted in ADA paratransit services, which provide public transportation for disabled people in need (15–16). The proposed model reduces about 25 percent of the inefficient trips in ADA demand services, while keeping the same traveling quality as previously. Furthermore, another study shows that the decentralized strategy increases the reliability of paratransit. On a smaller scale, ridesharing service is also provided by SuperShuttle or other private entities. In this case, ridesharing serves passengers to/from major airports from/to individual locations, such as homes or hotels. One aspect that needs to be pointed out is that ride-hailing services are instead different. UBER/Lyft or alike provide services very similar and alternative to taxis, without any significant ridesharing, if not improvised and negligible or due to already grouped parties of riders.

Beyond engineering fields, social studies also show the effects of ridesharing. The negative social interactions from passengers using ridesharing include feelings of prejudice, and unsafety when matched with different sex (17). Therefore, improving social negative impacts still needs further consideration. Sometimes, ridesharing requires a compromise effort for the passengers. In this case, passengers tend to satisfy some of their travel mobility freedom by sharing ride spaces with others. Considering unrealistic scenarios of taking a taxi with strangers, it is not natural to expect ridesharing to happen frequently. A systematic approach is necessary to stimulate ridesharing to occur in a sizeable and impactful way, in the form of effective incentives (18). A case study conducted experiments in Chicago (19) showed that about 50 percent of taxis' in-service time and travel distance were unproductive. Adverse impacts on the following aspects are obvious, including traffic congestion, service providers' profitability, vehicle emissions, and the quality of service. Full ridesharing services can reduce up to 75% of taxi vehicles on the road network (20). Therefore, involving partial taxis in ridesharing services may present incentives for transportation planners and policymakers to intervene in traffic congestion problems by incentivizing this switch. This action will improve the effectiveness of the transportation system, along with clear environmental advantages (21).

Based on the research gap, this study intends to investigate how ridesharing affects the total traveling mileage savings with the variation of a maximum matching rate between riders and drivers. The objectives of the proposed method are to maximize the total mileage savings and vehicle occupancy. Several aspects will be considered when formulating constraints: the maximum waiting time of riders (passengers' traveling quality consideration), travel distance of ridesharing trips, and maximum travel time increased in ridesharing mode.

3. Methodology

This section introduces the steps of how to group feasible passengers from two to four passengers in a shared trip, based on our previous research (22). Grouping four riders in a trip is idealized, but a shared trip with two or three riders is undoubtedly acceptable because participants' travel preferences should be considered. The study objective is to maximize the total mileage savings and decrease the number of useless trips on the road, which may further effectively reduce potential traffic congestion and air pollution. The proposed algorithm aims to match travelers into shared trips that generate the lowest mileage increment. First, the established model identifies the set of feasible travelers, time constraints are imposed: related to the user's tolerance in the waiting time for the ride to start and for the tolerance of the travel time extension. The next step is to select the best combination of participants in every shared trip to maximize total mileage savings. To explicitly explain the logic, we will start with the steps of a full ridesharing idea, followed by the conditions to match two riders with an available taxi. Then, the same logic will be applied to find the third and fourth feasible travelers to be grouped with the existing paired travelers. The results analysis returns the mileage savings, the average increase in travel time, and the number of grouped trips. The experiment results of sensitivity analysis promote the process of proposing effective and efficient policies.

3.1. Ridesharing Idea

This subsection introduces the idea of full ridesharing in steps. Figure 1. describes the different states in ridesharing (note that the case of matching three travelers together has not been shown in the figure, because of its similarity with the full ridesharing one). In single rides, one passenger travels on a single route with pick-up and drop-off points (endpoints of a travel route marked by dots with identical colors). The second model displays two pairs of travelers. The first and second passengers are matched together (the routes with green and blue endpoints, for example), similarly for the third and fourth passengers (the rest routes). The full ridesharing case involves matching four feasible travelers and assigning a vehicle to pick them up and decrease some useless travel distances, with only a small increase in detour distance on picking up and dropping off passengers. Also, the number of vehicles needed decreases from four to one, compared to the single rides case.

While the length of route taken per cab decreases, the increase in participants' travel time in the ridesharing system negatively affects their level of service. Therefore, our ridesharing model considers constraints related to maximum increased travel time to ensure passengers' travel quality. If the travel time with the ridesharing strategy exceeds the maximum increased travel time, this passenger will not join the ridesharing system. Similarly, we limit the maximum additional waiting time to ensure the travel comfort of drivers and riders.

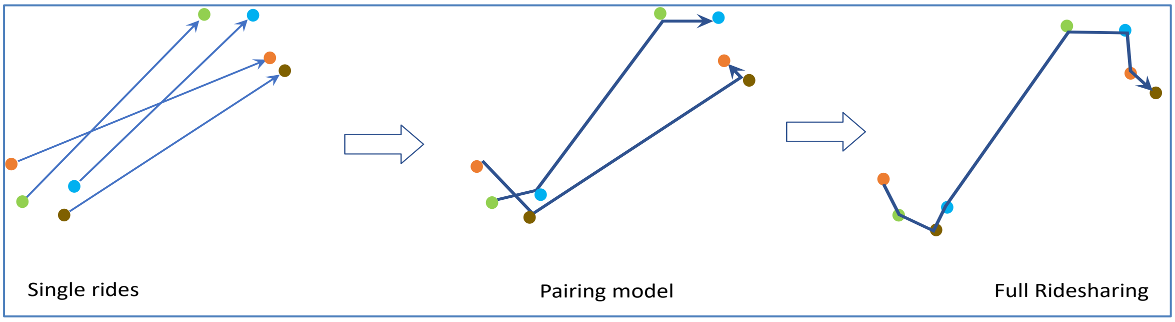


Fig. 1. The Logic of Matching at Most Four Passengers

3.2 Ridesharing Model Development

Preliminarily, a ridesharing model intends to show the case of pairing two passengers, and then the same logic will be generalized to the case of matching three and four passengers.

The assumptions of the ridesharing model include: 1) all travelers agree to share ride spaces with others; 2) trip start timestamp is the time that travelers are picked up by a taxi, since no passengers' travel schedule time is provided (once passengers are ready, they will be picked up); 3) the capacity of a vehicle is assumed to be four to satisfy the full ridesharing condition (more than one passengers can be picked up at one location, but the number of travelers in per vehicle is up to four within one ridesharing trip); 4) travelers are picked up or dropped off from every zone centroid, not the accurate locations (only centroid coordinates are provided in the dataset).

This paragraph shows the calculation process of travel distance and average trip speed. The distance between two coordinate points is calculated with the Manhattan distance formula. Manhattan distances are used in the places of actual (unknown) itineraries, proven to be an acceptable approximation of real transportation networks, particularly in the US large cities (*12*). The Manhattan distance formula fits the structure of Chicago city's road network. The simplified assumption of the road grid aligned with the vertical and horizontal distance components was adopted because the angle of rotation between the road grid and the Manhattan components is slight. Also, an average speed is assumed to be used for calculation in this model (assuming all vehicles have the same properties). The speed of one trip equals the result of trip distance divided by trip duration (provided in the dataset). Then, the average vehicle speed is the sum of the average speed of all trips divided by the number of trips, which is about 14.3 mph.

Trips for ridesharing experiments are then ranked by ready time and for every trip, feasible pairs of trips are selected when all following conditions are satisfied: 1) passengers' waiting time should be less or equal to a maximum waiting time parameter; 2) the total distance of ridesharing route should be less than the sum of trip distance from two single rides; 3) the time of new single route for both passengers from pick-up to drop-off locations should be less or equal to the product of a maximum ride time multiplier and sum of the time of the original route. If more than one pair of trips are feasible after filtering constraints, the pair of trips that maximizes the distance saving after pairing will be selected.

Figure 2 is to visualize the possible scenarios of two passengers' ridesharing. Letters O_z and D_z indicate the pickup and drop-off locations of passenger *z*, respectively. Similarly, O_s and D_s indicate the pickup and drop-off locations of passengers, respectively. Figure 2(a) shows the case of the single ride, as introduced in the ridesharing idea. Figures 2(b) and 2(c) indicate the route of a taxi to serve two passengers in a paired trip. In both cases, a taxi driver picks passenger *z* up at the position O_z and then drives to position O_s to serve passengers. The sequence could be inverse (passenger *s* first, then passenger *z*).

After picking up two passengers, the drop-off sequence may differ (see Figure 2(b) and (c), which is determined by the maximum mileage saving, compared to the case in 2(a). If the main difference is the distance from O_s to D_s and the distance from O_s to D_z. The sum of the rest distances is the same in the case of Figure 2(b) as that in Figure 2(c). If the distance between O_s and D_s is less than the distance between O_s to D_z, Figure 4(b) is the taxi route option. Otherwise, Figure 4(c) is the better option. The distance between O_s and D_s could be equal to the distance between O_s to D_z. In this case, either of the ridesharing routes is the choice.

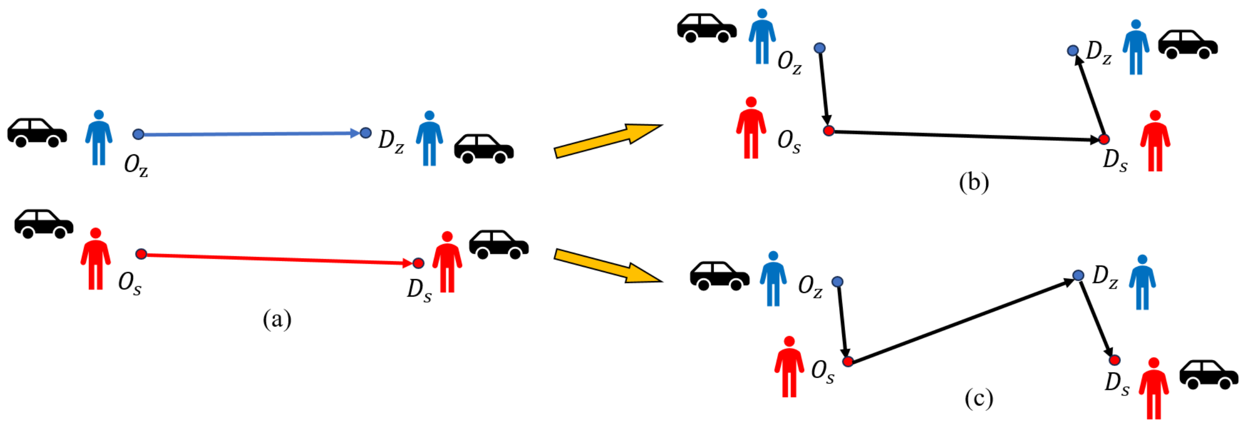


Fig. 2. Development of Pairing Ridesharing Model for Two Travelers

Parameters:

- d_{x-y}: distance from point x to y
- T_x: the ready time of passenger x
- V: taxi average speed
- K: the factor of maximum ride time multiplier
- W: maximum waiting time on starting

Variable:

- X_{o_d}: a binary variable to decide if the ridesharing trip is selected or not,

$$X_{o\_d} \in \{0,1\}$$

Objective:

Maximizing the total mileage saving:

- $\max \sum_{paied\ trips}(d_{single\ rides} \cdot X_{o\_d} - d_{ridesharing\ trip})$, *where* (1)

$d_{single\ rides} = d_{O_z-D_z} + d_{O_s-D_s}$, $d_{ridesharing\ trip} = d_{O_z-O_s} + d_{O_s-D_s} + d_{D_s-D_z}$ *or* $d_{O_z-O_s} + d_{O_s-D_z} + d_{D_z-D_s}$

Steps:

1. Initializing:

Input variables V, K, W

2. Pairing Model Constraints Checking (assuming traveler z is first picked up):

- Check the distances of separate trips and shared trips:

$$d_{single\ rides} - d_{ridesharing\ trip} > 0, \text{ if yes, } X_{o\_d} = 1, \text{ otherwise } X_{o\_d} = 0 \quad (2)$$

- Check the waiting time for every feasible pair:

$$\left|T_{start\ s} - \left(T_{start\ z} + d_{O_z-O_s}/V\right)\right| \leq W \quad (3)$$

- Check that the ratio of time in paired trips divided by the time of single rides does not exceed a maximum ride time multiplier:

$$(d_{ridesharing\ trips}/\ V)\ /\ (d_{single\ rides}/V) \leq K \quad (4)$$

Step 2.1 Aggregation:

- $Paired\ Trip\ Distance\ (total\ distance\ traveled\ by\ cab) = d_{ridesharing\ trip}$ (5)
- $Travel\ time\ start = T_{start\ z}$ (6)
- $Travel\ time\ duration$ (the sum of both travelers' distance)

$$= (d_{O_z-O_s} + 2 * d_{O_s-D_s} + d_{D_s-D_z})/V \text{ or } (d_{O_z-O_s} + 2 * d_{O_s-D_z} + d_{D_z-D_s})/V \quad (7)$$

- $Travel\ time\ end = Travel\ time\ start + Travel\ time\ duration$ (8)

Step 2.2 Save paired trip information in a table named paired trips

More explanation about the equation $T_{start\ s} - \left(T_{start\ z} + \frac{d_{O_z-O_s}}{V}\right) \leq W$ regarding waiting time should be explained further to avoid confusion. The term $T_{start\ z} + \frac{d_{O_z-O_s}}{V}$ calculates the time that a taxi arrives at position O_s to pick up passengers. Term $T_{start\ s}$ indicates the time that the passenger s is ready and starts the trip. The difference between them is the time that one passenger needs to wait for another at position O_s. If the vehicle arrives at position O_s earlier than the time that passenger s is ready, $T_{start\ s} - \left(T_{start\ z} + \frac{d_{O_z-O_s}}{V}\right)$ is positive and passenger z needs to wait for passenger s. The waiting time should not be larger than the maximum waiting time W. If the vehicle arrives at position O_s later than the time that passenger s is ready, $T_{start\ s} - \left(T_{start\ z} + \frac{d_{O_z-O_s}}{V}\right)$ is negative and passenger s needs to wait for passenger z. Now is the absolute value of $T_{start\ s} - \left(T_{start\ s} + \frac{d_{O_z-O_s}}{V}\right)$ should not be larger than the maximum waiting time W. Equation (3) is to ensure passengers' travel quality. Steps 2.1 and 2.2 record the information of paired trips for result analysis.

3.3 The Logic of Inserting Passengers

Based on the developed model of grouping two riders, we can insert feasible 3rd and 4th passengers (still not matched with any other riders) into the existing groups (shown in Figure 3). Now we have a group of two riders (taken as a whole, passenger *s*), and the goal in this step is to find a feasible rider *z* to match with this group (passenger *s*). If this new combination satisfies all the requirements listed in our model, a shared trip with three riders is formed. Similarly, this step will last until the optimized third rider is found. For the entire system, a feasible third rider will continue to be searched by the algorithm to insert into the existing groups with two riders until no feasible 3rd passenger can be added to existing pairs of passengers. The 4th passenger will be inserted into the existing groups with three riders until no such feasible riders can be found, and then all the steps end.

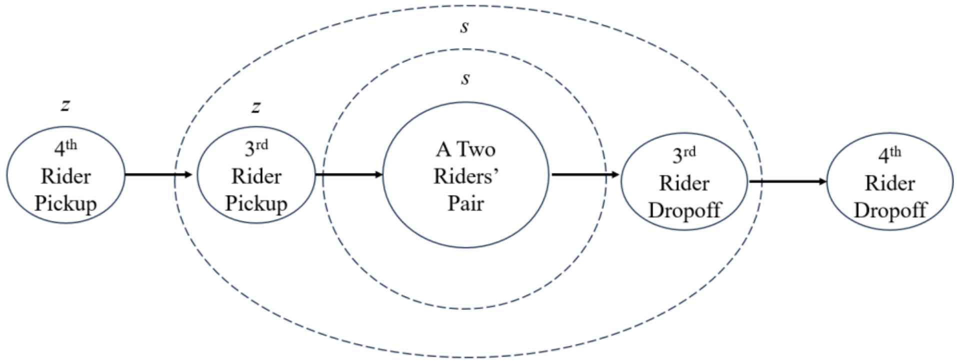


Fig. 3. Frame of Inserting Ungrouped Riders to Existing Groups

4. Experiments and results

The dataset used for this research contains four-week Chicago taxi trips in January 2019. It contains spatial-temporal information about trips, including trip ID, trip start and end time, pick-up and drop-off locations with centroid coordinates, trip duration, and distance.

4.1 Basic Ridesharing Experiments

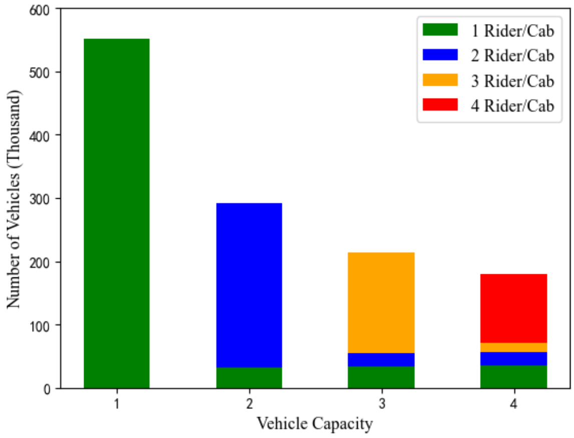
The first experiment investigates the differences between applying the ridesharing strategy and only single rides. Some representative indicators include the number of trips, the total distance traveled by cabs, the number of passengers involved in ridesharing, and the total time spent by passengers. The first scenario (Table 1) presents the experiment results with 4 riders as the vehicle capacity and 1.5 as the maximum ride time multiplier. After applying our ridesharing model, the total mileage saving is 1,281,636.50 miles (2,419,032.23 – 1,137,395.73), with a 52.98% total mileage decrease, compared to the case of no ridesharing. Meanwhile, since travelers agree to join ridesharing system with other passengers, the total journey time increases by 19,525.35 hours (188,788.06 – 169,262.72), about 11.54% increase, compared to the case of single rides. In the overall transportation system, more than 50% of mileage saving is achieved, while only 11% of travel time concession. This is a considerable benefit that ridesharing brings, but at the same time, the premise is that about 551 thousand people are involved in ridesharing mode.

From the maximum number of passengers in one vehicle, 107,159 vehicles serve four passengers. This number is much larger than those in the rest scenarios. The reason may result from the dataset we use and the proposed assumption. The dataset is from a large urban area and many trips originate from/to urban districts. Also, we assume that most all trips depart and arrive from the centroids of areas, because of the original trip information provided. Although the experiment results may vary in other situations, this proposed research method is still applicable.

Tab. 1. Results of Ridesharing with Four Passengers at Most (K = 1.5)

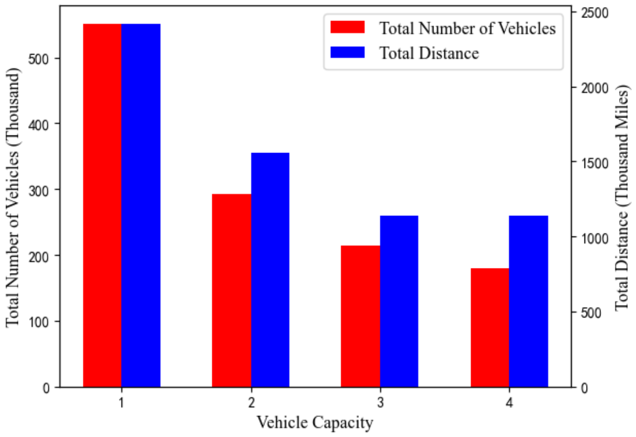
Number of Passengers	**Number of Trips**	**Total Distance for Taxi (Miles)**	**Total Time Spent by Travelers (Hours)**
4	107,159	715,385.90	146,437.45
3	15,098	124,107.09	16.758.67
2	20,731	139,191.50	14,487.15
1	35,953	158,711.25	11,104.80
No Ridesharing	551,345	2,419,032.23	169,262.72
With Ridesharing	178,941	1,137,395.73	188,788.06
Difference		1,281,636.50	19,525.35
Percentage Change (%)		-52.98	+11.54

Figure 4(a) depicts the total number of vehicles needed in the ridesharing system across different vehicle capacities. As the vehicle capacity increases, it is evident from the height of each bar that fewer vehicles are required. This illustrates the effectiveness of ridesharing in grouping trips with similar itineraries and reducing the useless trips in the system. In Figure 4(b), we observe a decrease in total mileage as the vehicle capacity increases. However, the variation in total travel distance is not significant between cases where the vehicle capacity is three and four. One reason for this could be the increase in average detour mileage to pick up and drop off riders per grouped trip, even though the number of vehicles in the case with a capacity of four is less than that of three. The experiment results also indicate the macroscopic effect of travel detours. Therefore, strategies such as meeting points strategy or other relevant methods that could mitigate this effect should be implemented in ridesharing systems.



(a)

Fig. 4(a). The number of Vehicles with Different Vehicle Capacity;



(b)

Fig. 4(b). The Number of Vehicles Needed and Total Mileage in Different Vehicle Capacity

4.2 Sensitivity Analysis Results

Table 2. shows the compared results from the cases that multipliers equal to 1.5 and 1, keeping the maximum number of passengers unchanged, which is four. The number of vehicles carrying four passengers decreases dramatically when K = 1, compared with the results when K = 1.5. When passengers refuse to increase the travel time to be matched with others, the mileage savings turn out to be about 18 percent. The number of single trips accounts for about 87 percent of the total trips. The rate of ridesharing trips decreases as the number of passengers increases. This case study is the most stringent one, describing the scenario when users are unwilling to accept travel detours. Passengers who agree to be served with ridesharing mode should allow a slight increase in journey time, otherwise, the function of ridesharing mode cannot be exerted. Therefore, traffic planners and policymakers may consider additional policies to activate passengers' passion of involving in the ridesharing system.

Tab. 2. Results of Ridesharing with Four Passengers at Most (K = 1.5 &1)

Number of Passengers	**K = 1.5**		**K = 1**	
	Number of Vehicles	**Total Distance for Taxi (Miles)**	**Number of Vehicles**	**Total Distance for Taxi (Miles)**
4	107,159	715,385.90	3,111	61,761.81
3	15,098	124,107.09	5,301	71,080.51
2	20,731	139,191.50	52,705	285,421.26
1	35,953	158,711.25	417,588	1,565,154.50
No Ridesharing	551,345	2,419,032.23	551,345	2,419,032.23
With Ridesharing	178,941	1,137,395.73	478,705	1,983,418.09
Difference		1,281,636.50		435,614.14
Percentage Change (%)		-52.98		-18.01

Figure 5 displays the simulation results for the cases of a maximum of two passengers matched with different combinations of maximum ride time multiplier K and waiting time W. As expected, more travelers will be matched when the value of the maximum ride time multiplier increases, because of travelers' high tolerance for increased travel time in ridesharing. While maintaining 15 minutes as the maximum waiting time, the total mileage dramatically decreases from $K = 1.2$ to $K = 1.5$. However, the change from scenarios 2 to 3 is negligible. It indicates that if we increase the maximum travel detour distance to 50%, almost all feasible participants will be grouped with other travelers. Considering the factors of travel comfort and implications of ridesharing models, we usually set the maximum ride time multiplier $K \leq 1.5$. In addition, compared with the base case ($K = 1.5$, $T = 15$ min), the case allowing unlimited waiting time results in the largest number of matched travelers. Based on our model, waiting time W would not be infinity, because it is also controlled by the parameter K. The low percentage of increased travel time indicates the usefulness of ridesharing algorithms in grouping passengers and reducing total mileage in large urban areas.

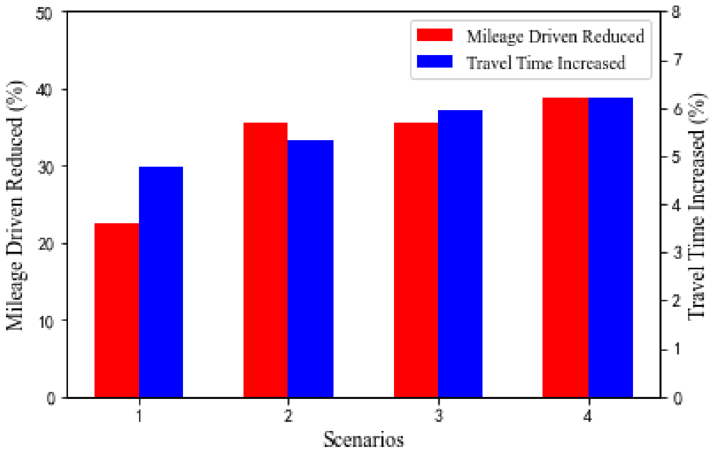


Fig. 5. Results of Ridesharing with Different Combination of K and Waiting Time (W)
* Scenario 1: K = 1.2, W = 15min; Scenario 2: K = 1.5, W = 15min; Scenario 3: K = 1.8, W = 15min; Scenario 4: K = 1.5, W = infinity;

5. Conclusion

This paper proposes a comprehensive simulation of switching taxi demand into ridesharing mode to evaluate the effect on traffic and passengers in large urban areas. We utilize a large dataset of Chicago taxis for our investigation. Our experiment results indicate that ridesharing strategy is one of the potentially effective solutions to reduce the effects of traffic congestion and gas emissions. because it matches passengers who have similar travel schedules to increase vehicle occupancy and decrease unnecessary vehicles on the road network. Simulation results validate the usefulness of the proposed model, with up to more than 50% driven miles decreased, while keeping the service level to an acceptable value. Sensitivity analyses show that the following actions result in more total mileage savings and quantify them: increasing the ridesharing capacity from 2 to up to 4, and the value of maximum ride time multiplier. The experiment seeks to equip planners and policymakers with tools and insights to encourage the partial transition of taxi services to ridesharing. This initiative presents a chance to enhance traffic conditions and improve the overall efficiency of the transportation system. Future studies should consider the effect of variable partial adherence of taxi passengers to ridesharing mode and how to incentivize the potential switch to increase the participation rate of the ridesharing system.

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Author Contributions

The authors confirm their contribution to the paper as follows: study conception and design: L. Quadrifoglio; data collection and analysis: C. Zhang; analysis and interpretation of results: C. Zhang, D. Ballarano, L. Quadrifoglio; draft manuscript preparation: C. Zhang, D. Ballarano. All authors reviewed the results and approved the final version of the manuscript.

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