The best taxicab strategy for a town

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Abstract. Taxi is an important means of transport in our life. With the development of the society, a taxi is convenient or not and its price may have a direct impact on the passenger's ride experience and the quality of life. There is no denying that it is necessary to discuss how to set prices, etc. In Model 1, we divide the whole city into four zones according to their functions .we establish the relation between average waiting time and taxi number based on the balance equation of supply and demand. According to the actual situation ,we calculate the minimum number of taxis, which satisfies the requests, is 127. In Model 2, we studied the conversion issue from zone-to-zone price to meter-based price. Single ride distances and the number of passing zones can be obtained by computer simulation. Using these data, we can calculate the single-pass income under the two pricing systems. What´s more, the correctness of Model 2 is verified by Washington´s real taxi price system. Finally, we develop suitable zone-to-zone price in this city, and work out the meter-based price is 200cent/mile.

1. Introduction

Mythical is a vibrant college town in the middle of Dompkins County. Local landmarks & destinations include university, attractions, downtown and an airport. People there using public transportation and taxicabs are mainly those with lower incomes and temporary residents (e.g., the students).Others use taxis primarily when traveling to/from the airport or the bus station. There are some unlicensed taxis with low service quality, so many customers are unhappy with the local taxi companies. The city and county officials are interested in improving the situation.

In order to assess the current needs and the likely consequences of any reforms and satisfy the demands of passengers greatly, we establish a model to find out the factors which determine the average passenger waiting time. In the case of other parameters are constant, discuss the relationship between average waiting time and the number of taxis. In addition, we find out calculation method of the conversion between zone pricing system and meter-based pricing system. According to this conversion formula, the revenues of taxicab companies should be roughly the same under the two pricing way.

2. Model I

2.1 Overview

We divide the whole city into four zones according to their functions .we establish the relation between average waiting time and taxi number based on the balance equation of supply and demand.

2.2 The supply-demand equilibrium model for taxis

Assuming the driver´s randomness of choice behaviors obey double exponential distribution[1], the probability of an empty taxi in zone j selects zone i as the search direction is

$$\mathrm{P}_{i/j} = \frac{e^{-\theta(\mathrm{u}_{ji}+\omega_i)\mathrm{Q}_i}}{\sum_{k\in I'_j} e^{-\theta(\mathrm{u}_{jk}+\omega_k)\mathrm{Q}_k}} (\mathrm{i} \in I'_j,\ j \in J) \tag{1}$$

$$Q_i = \sum_j D_{ij} \tag{2}$$

Where

u_{ij} is a taxi´s travel time of the shortest path from traffic area j to i

ω_i is the average search time in zone i

Q_i is the demand of taxis in zone i

D_{ij} is the number of taxis from zone i to zone j

θ is a non-negative correction factor

J is a collection of searching origin

$I_j^{'}$ is a collection of target area, which is traffic area adjacent to the zone j

According to the reference [1], we know the relationship between ω_i and N(the number of taxis)

$$\omega_i = (\mathrm{N} - \sum_{i \in I} \sum_{j \in J} \sum_{k \in A_{ji}} D_j \mathrm{P}_{ji}^k \mathrm{t}_{ji}^k - \sum_{i \in \{I-x\}} \sum_{j \in J} \sum_{k \in A_{ji}} D_j \mathrm{P}_{ji}^k \omega_i) / \sum_{j \in J} \sum_{k \in A_{jx}} D_j P_{jx}^k \tag{3}$$

we divide the Greater Mythical into 4 parts(just as figure 1)

The numbers on the picture mean the a taxi´s travel time of the shortest path between two traffic areas.

One point to note here is that these four areas do not just include these four locations, but using these four landmarks as its center, and they are not far from each other. These four landmarks´ exist only decides their travel demands.

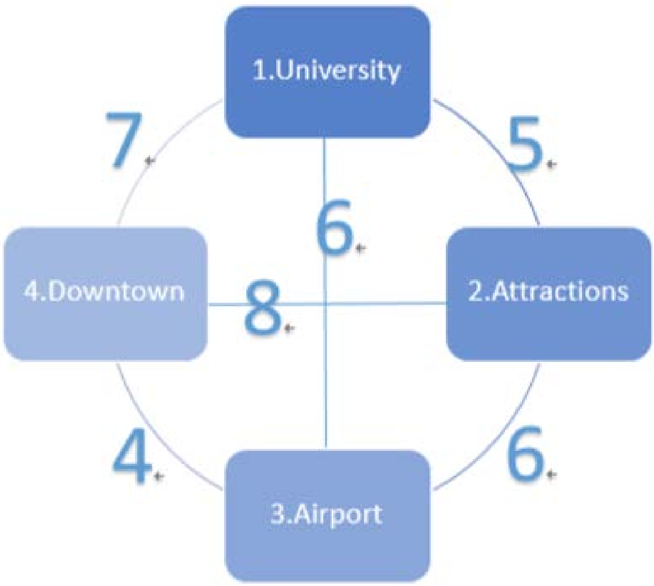

Fig1. Four parts of the Greater Mythical

The following describes how to satisfy the two requirements:

1. the average customer waiting time is ≤ 15 minutes

   The average customer waiting time ω_i is different from zone to zone, to meet the requirement 1, only need to let the maximum of ω_i less than 15 minutes. Because there is a corresponding relationship between the ω_i and N (expression 3).So, we can obtain the minimum of ω_i by using the maximum value of N.

2. less than 10% of customers end up waiting more than 25 minutes

   Assuming the average passengers waiting time satisfy normally distributed N(μ,σ2), and the expectation is 15 minutes. Standardize the normal distribution and the value corresponding to 25 is the quantile $Z_{0.1}$.By looking up data from table of standard normal distribution, we can obtain the following formula.

$$\text{Since } \frac{25-\mu}{\sigma} = Z_{0.1} = 1.29, \text{where } \mu = 15$$

We know $\sigma = 0.77$

$$\text{Then } \frac{T_{\max}-\mu}{\sigma} = Z_0 \approx 3.49$$

So Tmax = 42min. Parameter values which satisfy requirement 2 are determined.

3. Model II

3.1 Establishing

We studied the conversion issue from zone-to-zone price to meter-based price. Single ride distances and the number of passing zones can be obtained by computer simulation. Using these data, we can calculate the single-pass income under the two pricing systems. What's more, the correctness of Model 2 is verified by Washington's real taxi price system. Finally, we develop suitable zone-to-zone price in this city, and work out the meter-based price is 200cent/mile.

Regardless of the way we using to calculate the price, the major factor to determine the price level is mileage, so we assume that when a taxi driving at the same mileage, expects of driver´s income are equal. That is, we do not consider this situation: due to the travel demand of a certain area is relatively small, drivers are not easy to find new passengers, and therefore, zone-to-zone prices should be raised deliberately in this region. For the starting fare which is used to board a taxi, we are aware that its benefits mainly include the following three points:

1. If the starting fare is not set and the price only determined by mileage, then the driver's total income would increase accompanying mileage's increase, which is likely to cause the driver's intentional detour, so setting the start fare is necessary to safeguard the interest of passengers.
2. If there is no starting fare, there will be a lot of passengers with close travel distance also choose to take a taxi, which will not only undermine the profits of taxi drivers, but also cause traffic chaos. Therefore, higher fare is necessary and effective in limiting such behavior.
3. If there is no starting fare,inorder to guarantee the profits of taxi drivers, current price of per kilometer should be increased. For passengers who travel farther distance, they may be reluctant to pay the high cost of taxis and give up taking a taxi trip, which is a great loss for taxi drivers. After setting a starting price, for passengers travel closer, the benefits may be less than their spending, while long distance passengers opposite, so passengers prefer a taxi to travel long distances. And taxi drivers' profits can derive from the balance of these two types of visitors. Therefore, setting the starting fare is more reasonable than simply charging according to the mileage.

3.2 Solving

Step 1: Calculate driving distance expectations

Start and end points of the passengers taking a taxi are random, so two random numbers can be used to simulate start and end points. If the two points located within the two regions separated by n zones, then the distance between these two points is the expectation of distance of across the n zones.

Step 2: Obtain the expectations of the number of passing zones in a trip

Using ai to stand for the number of zones which is crossed in a trip is i. Instead of the location of this area with the center coordinates of the two regions, and the distance between two adjacent zones´ centers represent the increasing mileage for across a zone. As long as we know the distance of any two zones´ centers, the total number of zones to be passed when the start and end points are located in the two zones can be estimated. And the total number of zones to be passed between any two zones can be obtained by exhaustive method, so we can know probability of ai.

Then, we can use these datas to set the price of taxis.

we developed the following prices

(1) zone pricing system

The city is divided into 14 regions, each regional area remained at 5.1km2. When driving in one zone charges $ 5.5, extra $ 2.3 will be charged every time you spanning an area.

(2) meter-based pricing system

Start at $ 2.5, base price mileage is 0.2 mile, and then each additional 1 mile charges $ 2.

Result : $x = 200$

And then, we obtained:

Single-pass income under zone pricing system:11.2442$

Single-pass income under meter-based pricing system:11.7299$

Refer to the real New York City taxi prices[2], We can see that the results are reasonable. The price is $ 2.0286 per mile in New York´s meter-based pricing system, so the prices are inline with industry standards.By comparing the two calculationresults, we can ensure that the revenues of taxicab companies after changing billing method roughly the same as they are right now.

4. Summary

In order to improve the service quality of taxis, the scale is the key. Right number of taxis would not only shorten the waiting time of passengers, but won't cause a large amount of redundancy. Meter-based pricing system and zone pricing system both have advantages and disadvantages. Meter-based pricing system is used in most cities around the world and is more likely to be accepted by passengers. While for a taxi driver, two pricing methods are equivalent, but for passengers, meter-based pricing system is more equitable. Zone pricing system only applies to smaller cities. For larger cities, too many zones needs to be divided into, which leads to zone pricing system is more complex, and is more difficult to implement. So, meter-based pricing system is more pervasive.

We should choose the number of taxis and the way to charge according to actual condition.

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