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# Investigating the Value of Location Information in Taxi Dispatching Services: A case study of DaZhong Taxi

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## Abstract

*Location-based service is often quoted as one of the killer applications of mobile commerce. However, there is no theoretical analysis on the real value of location information in location-based mobile services. In this paper we introduce four types of dispatching models and analyze how location information is obtained and used to support dispatch services. The value of GPS-based dispatching services then is further analyzed through the case study of DaZhong Company in Shanghai, China.*

**Keyword:** mobile commerce, LBS, transportation, taxi dispatching, case study

## 1. Introduction

Nowadays, the development of mobile communication technologies made it possible for people to communicate with each other any time anywhere in the move without the restriction of fixed-line connection points (Yuan 2003). Besides voice and short message communication through the use of cell phones, a variety of new types of value-added mobile services became available through wireless Internet access. A typical example is NTT's DoCoMo in Japan that allow people book movie tickets, pay bank bills through the use of handheld devices such as cell phones. We refer the services provided to people through the use of mobile communication networks and mobile devices as mobile commerce. (Tsalgatidou, 2003, Steinfield, 2003).

A unique feature associated with the mobile communication infrastructure is the location identification capability through the use of GPS and other network-based technologies (Tsalgatidou 2003). These technologies made a new type of mobile location-based services possible. Location Based Services (LBS) takes the user's real time location into account in order to deliver a service related to his or her location (VanderMeer, 2001). There are many location-based services such as E-911 that helps police to quickly locate and rescue people who made an emergency call through cell phones. Driving or travel navigation is another example of LBS. In the recent years, many taxi service providers in the world have incorporated the features of LBS into their dispatching systems. There are two real cases. The first is *Zingo system* in London, a new service which allows passengers to hail a taxi by

calling a dedicated phone number from their mobile phone, through identifying the location of the passenger and the nearest taxi by using a global positioning system and location based services (LBS) (Transport, 2003). And other is *Automatic Vehicle Location and Dispatch Systems (AVLDS)* in Singapore, which makes the use of satellite-based dispatch technologies (Ziqi Liao, 2001).

As to transportation, dispatching is one of the operation research problems. Considerable research has been devoted to solving routing and scheduling problem, either based on deterministic distance and/or travel time criteria, or based on stochastic demands and more complex evaluation criteria. Interactive decision support system, local search techniques and genetic algorithm are also used in the research of vehicle dispatching (Malmborg, 1996).

However, no theoretical work has been done to analyze the value of real time location information in the field of Taxi Dispatching Services. We conducted a survey on the taxi dispatching in Shanghai, China. We interviewed with several senior managers in taxi companies, 50 taxi drivers and 100 passengers respectively. In this paper, we will discuss the value of location information based on the taxi dispatching modes, including random-searching mode, fixed-stop mode, broadcasting mode and GPS-based mode, and finally analyze a number of issues, such as which mode fits which situation, supporting technology, and benefits and costs for passengers, for taxi drivers and for taxi companies. It commences with the analysis of four dispatching modes, followed by a brief summary. Case study is then presented on the basis of statistical analysis of empirical data and vivid stories collected from the survey.

## 2. Dispatching Mode

What benefits does real-time location information bring to the taxi dispatching services? As we all know, the objective of taxi dispatching is to provide passengers with taxi services effectively and efficiently, based on the location of taxi, passenger, departure and destination. In other word, match the calling passenger and available taxi properly in term of distance and availability with two rules – “nearest vehicle first” and “least utilized vehicle first” (Shrivastava, 1997).

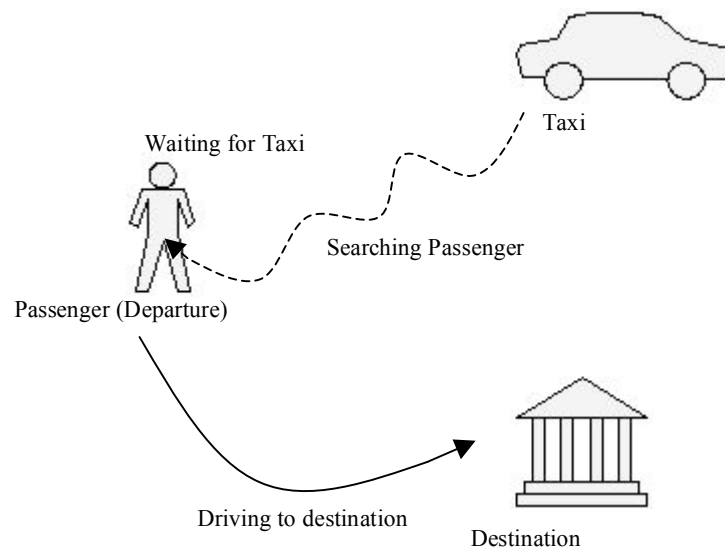
Considering the availability of location information of passengers and taxis respectively, we can have four possible combinations. Correspondingly there are also four typical taxi dispatching modes: random-searching mode, fixed-stop mode, broadcasting mode and GPS-based mode shown in Table 1.

**Table 1 Classification of taxi dispatching modes**

Location information	Taxi location is unknown	Taxi location is known
Passenger location is unknown	Random Searching mode	Fixed stop mode
Passenger location is known	Broadcasting mode	GPS-based dispatching mode

### Random-Searching mode

In this mode, passenger is waiting for a taxi on street and empty taxi is moving around looking for a passenger, both passenger and taxi do not know each other’s location. Passengers and taxis are randomly searching for each other (See figure 1).



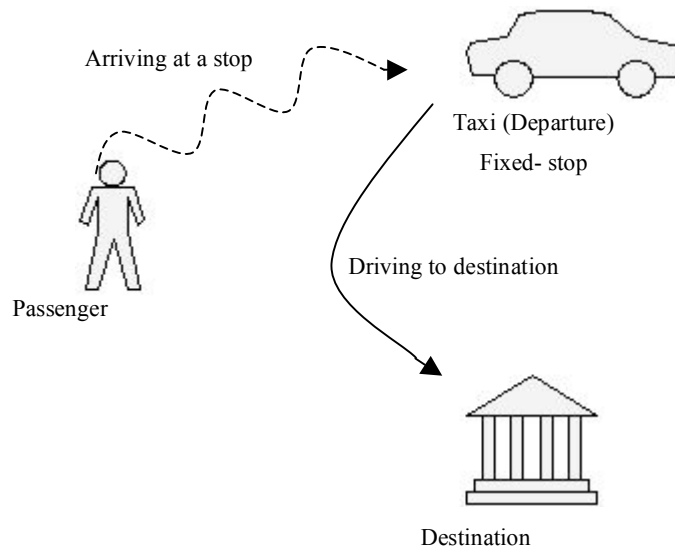
**Figure 1: Random-searching mode**

This mode is actually the most common one. In this mode, when a passenger needs a taxi, the only thing he or she can do is standing on street and waiting for a vacant taxi passes by. The waiting time of the passenger depends on the probability that a vacant taxi passes by during his/her waiting. This probability also depends on the time and passenger's waiting location. More cars may pass on a busy street, and during rush hours there may be few vacant taxis passing by. An unlucky passenger may wait long time without meeting any available bypass taxi, For the driver of a vacant taxi, he/she has to keep moving the taxi and hopes to find a passenger waiting on the bypassing street. Since the location of potential passenger is unknown, the taxi driver has to decide which street to roam through in order to increase the probability to meet a passenger. The unproductive idle driving and waiting time is caused by lack of taxi and passenger location information. In a big city usually there are so many idle taxis roaming around. It causes traffic jam and air pollution. It also results traffic accidents when a taxi driver is looking for a passenger without paying enough attention on driving. The random search mode does not require a centralized dispatching center. It is a flexible way to deal with the situation when both passenger and taxi location is not available.

According to the survey conducted in Shanghai, China, the percentage of empty miles ((total miles-service miles)/total miles) for taxi is 32%, while the waiting time for passenger may extend more than 1 hour in the rush hours at the worst. Definitely, this mode is not efficient and effective and there is a room to improve it.

### **Fixed-stop mode**

In this mode, taxi is waiting for a passenger at a heavy traffic center or stop point. The location for taxi is known but the arriving passenger is unknown. (See figure 2).



**Figure 2: Fixed-stop mode**

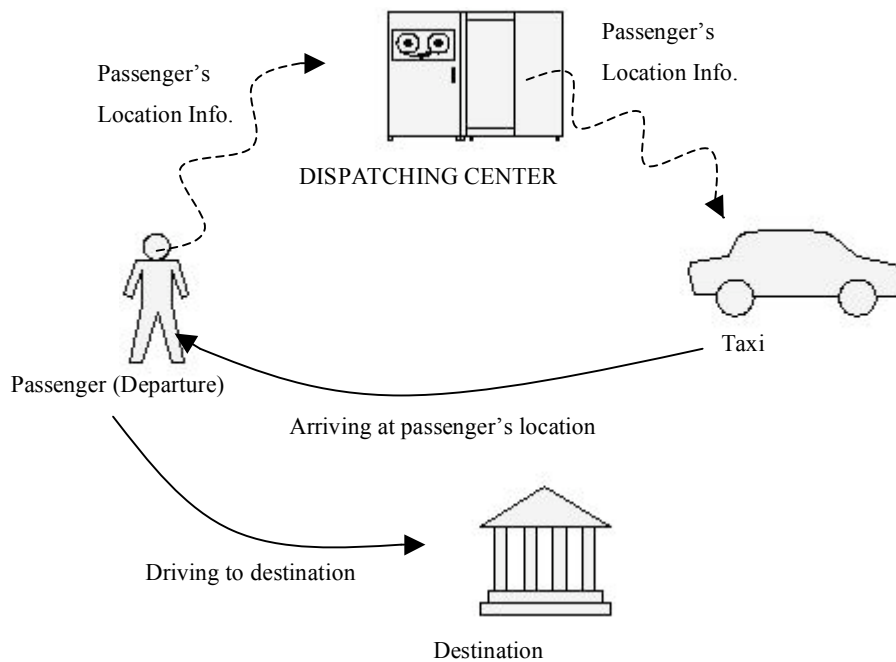
This mode can be frequently found at airport, hotel, and hospital. Usually, the available taxi is waiting at the parking lot next to the station, and when the passenger needs a taxi, he (or she) can get to the taxi stop and take a ride.

This mode is convenient for the nearby passengers such as arriving airline passengers, hotel guests and hospital patients to catch a taxi but not suitable for a passenger randomly walking on street. For a vacant taxi, it reduces empty driving searching for passengers but the waiting time could be very long. From other side, if a taxi only serves at a fixed stop such as airport, it may also cause empty driving on the way back to the airport after sending a passenger to the destination. In Singapore, the government set up fixed Taxi stops around city similar to bus stops so passengers can go to the taxi stop and taxi will also go to the taxi stop waiting for passengers. In this way, random searching is avoided.

The waiting taxis stands in a line to wait for passengers in the fixed stop. After several interviews with taxi drivers, we find that the average day waiting time of taxi at Pudong International Airport in Shanghai to get a passenger is 15 minutes. And the taxis in hotel stop will wait longer.

### **Broadcastng mode**

In this mode, passenger makes phone call to tell the location of the passenger to the dispatching center. The dispatching center manually get passenger's location information. However, the dispatching center does not know the current location of available taxis. Radio broadcast is therefore used by DISPATCHING CENTER to notify all the taxi drivers the need of a passenger and the location of the passenger by pagers in taxis. Taxi drivers then make their responses through two way radio based on their relative location and willingness to take service. (See figure 3).



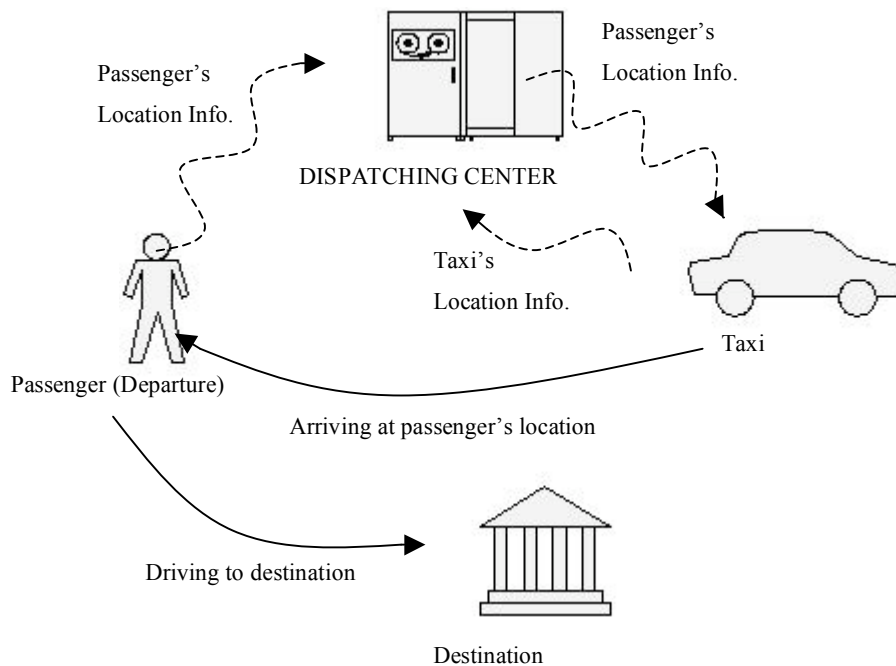
**Figure 3: Broadcasting mode**

In this mode, the passenger's location information is passed to dispatching center so there is no need for a passenger searching for a taxi. The taxi drivers also need not search for passenger by simply responding to the dispatching center. However, since the DISPATCHING CENTER does not know the location and the status of the taxis, it has to rely on drivers' responses to place the order without optimization. The manual, verbal information transformation is slow and the radio broadcasting creates noise and disturbs most unrelated taxi drivers and passengers.

From the same survey above, we found that to respond to a passenger's request, it usually takes a receptionist more than 3 minutes to identify an available taxi. About 70% of passengers show the dissatisfaction on the noise generated by the broadcast.

### **GPS-based mode**

In this mode, the taxi is E-dispatched with the GPS technology. The dispatching center automatically traces all taxis' location through wireless communication with a GPS device installed on the taxis. When a passenger requests a service through a fixed line phone, the dispatch center manually records passenger's location information at the first time. Next time, the system will automatically identify the location of the customer by the phone number. For a passenger calling with a cell phone, his or her location can be automatically collected by using cell phone locating technology in the future. (See figure 4)



**Figure 4: GPS-based mode**

By knowing both passenger's and taxis' locations, the DISPATCHING CENTER can determine which taxis are available nearby to serve the passenger. Specifically, this system works as follows. When a passenger needs a taxi, he can send a request for taxi service through a wired phone, a mobile phone or Internet. DISPATCHING CENTER will take the request and obtain the location of the passenger and taxis manually or automatically by GPS (Global Positioning System). After the locations of both are known, DISPATCHING CENTER searches the circular area where the centre of the circle is the location of passenger, and the diameter is 1 kilometer. Then if there are some taxis available, the DISPATCHING CENTER will choose the nearest taxi to the waiting passenger, and order the taxi to pick up the passenger. DISPATCHING CENTER will send the taxi registration number and the estimated arrival time back to passenger. The progress of dispatching is automated all around. If any available taxi can't be searched in this area, the diameter will be mounted up to 2 kilometer, next 3 kilometer, at this time, if there is still no available taxi, the DISPATCHING CENTER will report the passenger the sad news.

In this mode, for drivers, it is time-saving to follow the map to pick the passenger without the need of searching for customers. And more importantly, all the taxis are under the surveillance of the taxi company in order to optimize the dispatching assignment. However, before receiving any request from e-dispatching center, a vacant taxi may still use the random searching mode looking for ad hoc passengers. And for passengers without phone access, the random searching or fixed-stop mode are the available choices.

For passengers, it becomes very convenient to call a taxi through e-dispatching center with average confirmation time less than 1 minute and the passenger's waiting time less than 15

minutes in Shanghai, China.

### 3. Value of location information on dispatching services

The availability of location information determines the use of different taxi service modes. We can formulate a figure below (Figure 5) to explain the relationship between these four kinds of modes.

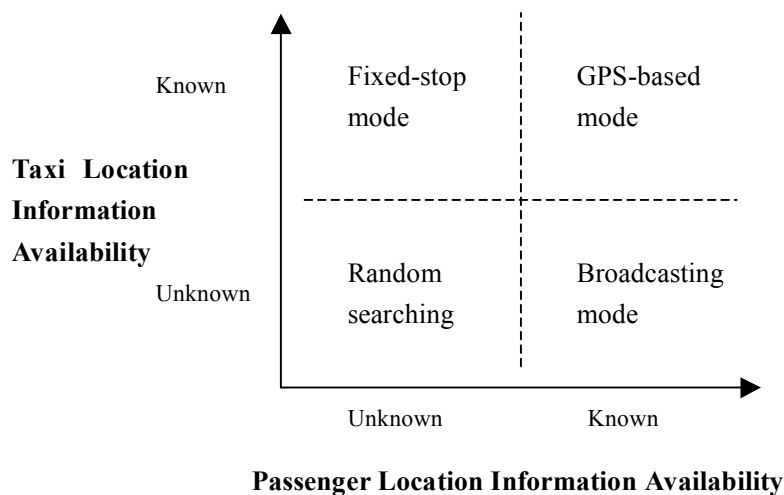


Figure 5: The relationship between four modes

The passenger location information reduces the cost for passenger searching for taxis and taxis searching for passengers. It can be made available through the use of dispatching center by passengers. It enables the shift from random searching mode to broadcasting mode or GPS-based mode.

The automatic collection of taxi location information through GPS makes the shift from broadcasting mode to GPS-based mode. It helps to optimize taxi dispatching therefore reduce the cost of carrying the passengers.

The pros and cons from passenger, taxi driver, and company perspective are summarized in the following table.

Table 2: Pros and Cons of different taxi dispatching modes

Dispatching mode	Pros and Cons
<b>Random-searching mode</b> Unknown passenger's Location Info. Unknown taxi's Location Info.	Flexible but with great uncertainty of passenger waiting time.
	Cost of empty taxi driving searching for passengers
	Unnecessary traffic jam and air pollution, Low utilization of taxi resource.
<b>Fixed-stop mode</b> Unknown passenger's Location Info.	Convenient for passengers nearby the stop but not available for other passengers to access



Known taxi's Location Info.	No need for empty taxi driving for searching for passengers, but may have long taxi waiting time.
	One way traffic revenue
<b>Broadcasting mode</b> Known passenger's Location Info. Unknown taxi's Location Info.	Reduce uncertainty. Easier for a passenger to get a taxi
	Reduce the need for driver searching for a passenger.
	Low cost dispatching service, suboptimal dispatching based on drivers' response..
<b>GPS-based mode</b> Known Passenger's Location Info. Known Taxi's Location Info.	Reduce uncertainty. Easier for a passenger to get a taxi
	Reduce the need for driver searching for a passenger.
	High cost of GPS system installation and operation, quick response, optimal dispatching assignment.

From the above table, we can find these four type dispatching modes have their own features, and may fit different situation. For example, fixed-stop mode is fit for airport while random-searching mode is fit for ad hoc request of taxi in a heavy traffic area and GPS-based mode is suitable for less taxi traffic area.

Although passenger location information can reduce searching cost and taxi location information can help to optimize the dispatching, here is cost associated with the collection of these information. The benefit should be justified by the cost under different situation. For example the random searching almost cost nothing, fixed-stop's expense is less, but the Dispatching System with GPS is very expensive.

#### 4. A Case Study

DaZhong Company, a market-leader in Shanghai, China, was founded in 1988, December 24<sup>th</sup>. Till the end of 2003, DaZhong Company's asset and equity have reached 5.3 and 2.3 billion RMB respectively. Up to now, DaZhong Company possesses more than 8,500 taxis in Shanghai and sets up other nine chain companies outside Shanghai.

Due to the increased demands for taxi services and slow response and less efficiency of the broadcasting mode, DaZhong Company decided to phase out the broadcasting systems and switch to a GPS-based dispatching systems by installing a GPS equipment (Figure 6) in many of its taxis (about 4,000 cars) as part of a new in-cab control system and upgrading DaZhong Dispatching Center (DZDC) from broadcasting mode to GPS-based mode.



**Figure 6: A GPS equipment installed in a taxi**

DZDC keeps track of the current location of all the taxis equipped with the GPS devices. Their locations are displayed on the E-MAP shown in Figure 7. In the E-MAP, a red car icon represents a busy taxi, green car icon represents an empty taxi, and blue car icon represents a taxi which is on the way to passenger's pick up point. Through this E-MAP and GPS devices, DZDC can acquire the real time location information of each taxi automatically.

A customer can utilize a public phone call (specifically 8621-96822) to book a taxi at DZDC. Immediately, a human operator or an automated voice guides the customer to provide the personal information and pickup point (through human communication, DZDC acquire the location information of each passenger manually). Also, a customer can use a facility that links to [www.96822.com](http://www.96822.com) to reserve a taxi. A customer is required to send in details such as name, time, pick-up address, the type of taxi, and the number of taxis required.

After collecting the passenger request information, DZDC automatically locates the nearest available taxi within the customer's area (About 1000 meters) through the E-MAP and sends the passenger's pick-up request to the taxi. As soon as the taxi driver accepts the request by push a bottom in car, the pick up address will appear on the display terminal of the taxi, while the customer is provided simultaneously with the taxi registration number and the estimated arrival time.

To investigate the value of location information in DaZhong Company, we mainly compare the value of GPS-based dispatching mode with that of Broadcasting mode for DaZhong Company, for the reason that DaZhong first deployed Broadcasting mode and now GPS-based one. However, this doesn't mean we will discard Random-searching mode and fixed-stop mode in the case study. Actually, DaZhong Company employs all 3 types of dispatching mode: Random-searching mode, fixed-stop mode, and GPS-based mode.

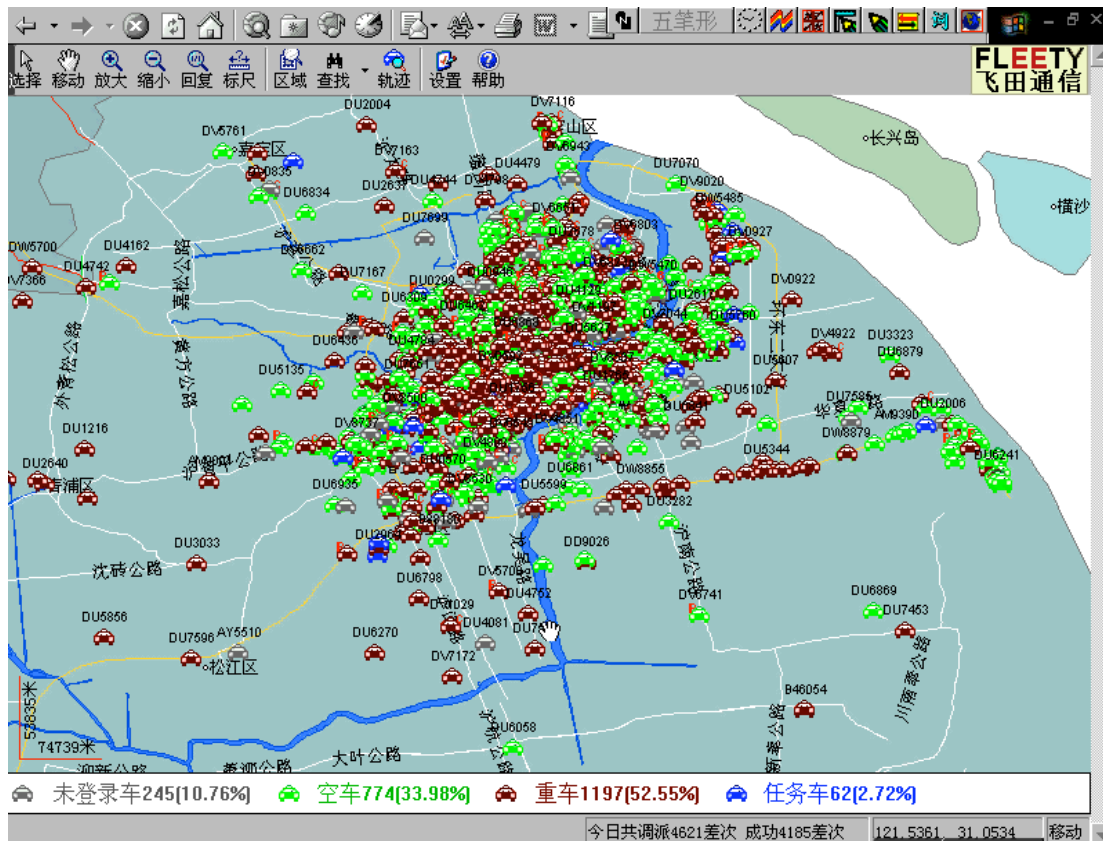


Figure 7: E-Dispatching Map of Shanghai City

We will analyze the value for four participants in the dispatching event: passenger, taxi (driver), company, and society.

For passenger: First, by the Broadcasting mode the average waiting time is about 30 minutes, but with the GPS-based mode it is less than 15 minutes. Second, in the survey we mentioned above, more than 70% of passengers complained about the noise of radio broadcasting but there is no noise in the taxi equipped with GPS technology. Third, the navigation guide provided by DZDC to the taxi driver also helps to optimize the routing to the destination therefore helps passenger save the mileage charge.

For taxi: First, the percentage of empty miles ((total miles-service miles)/total miles) is reduced from 32% to 16% in the GPS-based mode. Second, due to the empty mile, a taxi driver has to pay additional money for gas, but taxis equipped with GPS devices pay less. Third, with the help of E-MAP, the navigation of taxi becomes more rational, which reduces the percentage of empty miles indirectly. Forth, taxis with GPS devices are safer than ever, for these taxis are under the surveillance of DZDC, so the number of stolen taxis per year is decreased greatly. A taxi driver can push an emergency button to inform DZDC when he feels unsafe with a strange passenger. With this security feature no robbery case has happened after the installation of GPS.

For company: Through GPS technology, DaZhong Company can track every taxi's location information, decrease the probability that the taxi driver decides to take the order or not, and improve the response time from 3 minutes to 30 seconds. By the first and the only one company introducing the GPS technology, DaZhong became the market leader in Shanghai,

and its revenue increased greatly.

For society: First, the traffic jam in Shanghai is well-known, and GPS-based dispatching mode is of significant help to improve this status. According to a survey conducted in Shanghai, if the taxi empty miles is reduced by 1%, the number of vehicles running on the road will be reduced by 266. Second, environment conservation is another question. According to the same survey above, reducing 1% of empty miles means cost saving of 16 million RMB for gas as well as the reduction of air pollution (Tao, 2005). Third, GPS-based dispatching system also helps to stop criminal. As a real case, it helped policemen to arrest two criminals once. Through the E-MAP, the policeman tracked the taxi on which the criminals were sitting. Using the GPS communicator, the driver kept close touch with the policeman. And finally, these two criminal were quickly arrested without anybody hurt.

GPS-based dispatching mode brings in great value for Dazhong, but different modes can fit different situation. DaZhong Company does not discarding other modes, such as random-searching mode and fixed-stop mode, it is the combination of these modes that make a Dazhong's day.

Although the GPS-based dispatching system is of great benefits to DaZhong Company, but during the initial stage, the drivers in the company reject to accept the orders by the system. Because the passengers don't pay anything for this dispatching mode, for customers, the cost of booking is equal to the cost of random selecting. Furthermore, the drivers must wait in the downstairs of the passengers for more than a quarter, the waiting time is not included in the charge, some inurbane passengers may procrastinate for long time, this damages the benefits of drivers. To increase customer satisfaction and make taxi booking more reliable, DaZhong Company requests their drivers to fulfill 4 obligatory booking orders by GPS-based dispatching system in rush hour of every day.

## **2. Conclusion and further research**

The use of different taxi dispatching modes depends on the situation and availability of location information on customers and taxis. The real time location information on both customers and taxis helps to reduce searching time and cost for both customers and taxis. It also helps to optimize the dispatching, reduce response and dispatching time. As a consequence, it also helps to alleviate the traffic jams and reduce air pollution. It is clear that DaZhong Taxi has successfully established its market leading position and has won a large population of customers with the help of mobile technology. The use of the up-to-date GPS technology radically changes the traditional approaches to taxi dispatching and enables companies to enhance customers' satisfaction. We believe that the GPS-based dispatching systems will play an increasingly important role in the further improvement of their operations and services.

This paper is still in initial stage, to further enhance the evidence and the analysis, we will create our theoretical framework and the computing model for the value of four modes, we will develop the survey questionnaires based on our framework, then collect the data and analyze the results.

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