International Journal of Engineering Research-Online
*A Peer Reviewed International Journal*
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.7., Issue.2, 2019
Mar-Apr

RESEARCH ARTICLE

ISSN: 2321-7758

# PARKING BEHAVIOUR ANALYSIS OF LOCAL-USED NON-LOCAL VEHICLES BASED ON PARKING BIG DATA

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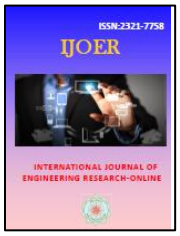
https://doi.org/10.33329/ijoer.72.22




**ABSTRACT**
To investigate the behaviour patterns of local-used foreign vehicles and analyse the socio-economic impact that the restriction policy which aims at these vehicles may bring, the parking behaviour patterns of foreign vehicles have been analysed using clustering algorithm, the results show that there are four parking patterns for non-local vehicles and 19% of them are local-used vehicles, which are mainly used for commuting or commercial activities. The implementation of the travel restriction policy will bring socio-economic impacts such as the increase of business costs and taxi passenger volume in Guangzhou city. The conclusions can provide a new perspective for the researches on vehicles behaviours and can also provide data supply for precisely managing non-local vehicles.
Keywords: parking data; vehicle behaviour patterns; clustering algorithm; vehicle restriction policy

## INTRODUCTION

The problem of "parking difficulty" is becoming more and more serious since the increasing number of urban vehicles; this problem not only affects people's travel experience, but also affects the urban traffic flow, resulting in the decrease of travel efficiency. To ease urban traffic pressure, Guangzhou became a limited vehicle purchase city from 30 June, 2012. The purchase restriction policy has effectively improved traffic condition. However, a part of citizens avoided this purchase policy by using non-local vehicles, which weakened the government's control effect and the traffic pressure has not been thoroughly addressed. Accordingly, Guangzhou city implemented a travel restriction policy aimed at non-local vehicles in 1st July, 2018 to precisely control non-local vehicles, the main contents of this travel restriction policy is as follows: the longest running time for non-local vehicles in a prescribed area shall not exceed 4 days, and there must be more than 4 days (contain) before they enter this area again.

Under the unique social and economic environment of Guangzhou, the local-used non-local vehicles also bear certain social functions, the implementation of the travel restriction policy for non-local vehicles will inevitably have an impact on the social and economic effects which come from this part of non-local vehicles. To quantify this impact, it is necessary to clarify the proportion of local-used non-local vehicles and understand the behavioural patterns of this part of vehicles. Up till now, many studies on vehicle behaviour characteristics based on parking data have been carried out around the world, the data of these researches mainly come from video surveillance and questionnaire survey of parking lots. For example, Tanaka et al[1] analysed the influence of parking facilities layout on driver's parking choice based on video surveillance data, Golias et al[2] analysed the sensitivity of drivers to the choice of roadside

parking lots based on 317 questionnaires. The analysis of parking behaviours is mainly based on the pre-classification of vehicles, Marsden [3] sorted vehicles into commuting, non-commuting, residential and other categories, summarized the impact of a series of policies on parking behaviour for various types of vehicles. Pan sorted vehicles according to travel purpose[4], while Guan[5] carried on the research on the choice of parking time in urban commercial districts. These studies reveal the parking behaviour characteristics of a certain type of vehicle or in a single area, but they are based on artificial classification which means the classification results depend on subjective judgment to some extent, and the amount of sample data is small. While in this paper, unsupervised clustering algorithm is carried out and this data-driven method can reveal the parking behaviour of vehicles directly from the angle of data[6]-[8], which is different from researches above and thus can provide a new perspective for the study of vehicle parking characteristics.

Many cities in China have formulated the travel restriction policy, such as travel restriction by tail number in Beijing City[9], by single/double license number in Luoyang City[10], and travel restriction during peak hour in weekday in Shenzhen City[11], and travel restrictions by limited continuous travel days in Guiyang City and Guangzhou City[12]-[13]. However, existing studies focus on the impact of restriction policies on traffic condition and air pollution [14]-[15], there are rare researches about the impact of restriction policies on society and economy.

Based on the above background, this article aims to explore the following questions from data-driven prospective:（1）Proportion of local-used vehicles.（2）Behaviour patterns and characteristics of local-used non-local vehicles.（3）The impact that travel restriction policy may have on society and economy in Guangzhou City.

Clustering analysis of parking behaviours for non-local vehicles in Guangzhou City

*Date Description*

The data of this article come from about 200 parking lots in Guangzhou City. Each parking record contains details such as vehicle license number, entry time, departure time, parking lot address and so on. The distribution of parking lots and travel restriction policy boundary are shown in Figure 1.

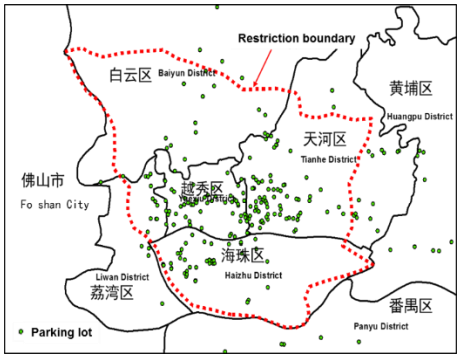



Fig. 1Parking lots distribution

*Selection of Clustering index*

The clustering indexes should reflect the characteristics of parking behaviour, and ensure the accuracy and convenience of data collection. Based on the obtained data, parking area, parking period and parking time length have been chosen to describe the parking behaviour of vehicles.

In most situations, drivers choose parking lots near their destination which is highly associate with their travel purpose, so the parking areas index can well describe the driver's travel purposes. The parking areas index is divided into 5 categories: residential area, commercial areas, office areas, public areas and hotel parking lots.

The parking period index is divided into 4 categories in one day: morning\evening peak hour, night period and day-time period (the rest of the day). The details time table can be found in table1.

Table I: Time table details

| Time period category | Time period |
|---|---|
| Morning peak hour | 7:30-9:30 |
| Day-time period | 9:30-17:00 /00:00-7:30 |
| Evening peak hour | 17:00-19:30 |
| Night period | 19:30-24:00 |

Parking time length is also an important index to describe the parking behaviour since it reflects the resource occupancy characteristics on parking facilities. The parking time length of each parking record is calculated according to the entry time and departure time. It should be noted that about 1.7% of the vehicles parked longer than 24 hours which belong to low frequency parking vehicles, have been excluded in this study.

*Determination of the Clustering Number*

After Z-score standardization of data [16], the clustering number K can be determined through experience or sum-of-squared error (SSE) method, the SSE method[17] is used and the calculation result is shown in Figure 2. It can be concluded from Figure 2 that when the clustering number K increases, the aggregation degree of samples increases and the SSE decreases. In the earlier period when the K value is smaller, the SSE decreases rapidly. But when the clustering number K reaches a certain value, the SSE decreases slowly and tends to be flat. The certain value, which is at the inflection point, is the recommended clustering number. According to Figure 2 and experience in related work, the clustering number 4 is selected for k-means clustering analysis.

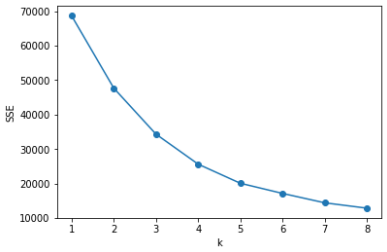



Fig. 2 K-SSE curve

*Clustering Result and Parking Behaviour Analysis*

The clustering results of non-local vehicles calculated by K-means algorithm are shown in Table 2.

Table 2: Clustering Results of Non-Local Vehicles

| Category | Parking areas | | | | | Parking periods | | | | Average parking time length /hour | Number of vehicles |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential areas | Commercial areas | Office areas | Public areas | Hotel parking lots | Day-time | Morning peak hour | Evening peak hour | Night period | | |
| C1 | 20% | 72.9% | 7.1% | 0 | 0 | 53.2% | 8.1% | 23.1% | 15.6% | 2.1 | 11643 |
| C2 | 0 | 0 | 48.8% | 40.7% | 10.5% | 72.7% | 13.2% | 8.1% | 6% | 2.2 | 5734 |
| C3 | 0 | 0 | 47.3% | 45.2% | 7.5% | 18.8% | 32.6% | 21.3% | 27.3% | 12.4 | 2279 |
| C4 | 67.1% | 32.9% | 0 | 0 | 0 | 18.6% | 16.2% | 28.4% | 36.8% | 13.1 | 3257 |

As can be seen from Table 2, there are 4 categories for the parking behaviour patterns of non-local vehicles. The first category (C1) and the second category (C2) are both short-time parking patterns, the average parking time length of which are around 2 hours. The third category (C3) and the forth category (C4) are both long-time parking patterns compared with the first two categories. According to the number of vehicles for each category, it is concluded that non-local vehicles prefer short-time parking patterns, as the proportion of this part of vehicles is 75.8%.

For the short-time parking vehicles, the parking characteristics of C1 vehicles is that they mainly park in commercial areas, especially during day time period and evening peak hour. C2 vehicles mainly park in office areas and public areas, and the proportion for hotel parking lots of C2 vehicles is much higher than other categories, the parking period of C2 vehicles is more significantly concentrated in the day time.

There is a complementation in the parking areas between C3 vehicles and C4 vehicles as Table 2 shows. The main parking areas for C3 vehicles are office areas and public areas, and morning peak hour parking gets the highest proportion in C3 vehicles, besides, the average parking time length is up to 12 hours, all these characteristics of C3 vehicles are consistent with the local vehicles for commuting use. For C4 vehicles, the main parking areas of this category are residential areas, evening peak hour and night period occupy the most proportion, similar to local vehicles returning home at night.

## IMPACT ANALYSIS OF TRAVEL RESTRICTION POLICY

According to the rules of the new travel restriction policy of Guangzhou City, there are 4,338 vehicles which violated this policy among 22,913 non-local vehicles, up to 19%. The number and proportion of violated vehicles in each category are shown in Figure 3. It shows that C4 vehicles has the highest violation proportion which is 28.9%, C3 vehicles follow as 22.2%, since they are both belong to long-time parking vehicles, it can be concluded that the travel restriction policy has a stronger impact on long-time parking non-local vehicles.

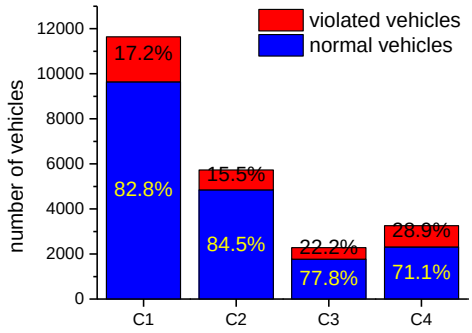



Fig. 3 Proportion of violated vehicles in each category

Figure 4 shows the parking areas distribution of violated vehicles in each category, the largest number of violated vehicles is in C1, and they mostly parked in commercial areas, combined with the 2 hours average parking time of this category, we can infer that this part of vehicles may be used for commercial activities in Guangzhou. Violated vehicles in C1 are also short-time parking pattern which may be the online cars operating in office areas and public areas. According to the characteristics analysis above, violated vehicles in C3 and C4 have the similar patterns with local vehicles for commuting use, this part of non-local vehicles may come from citizens who can not buy vehicles with local licenses due to the purchase restriction policy while turning to use vehicles with non-local licenses.

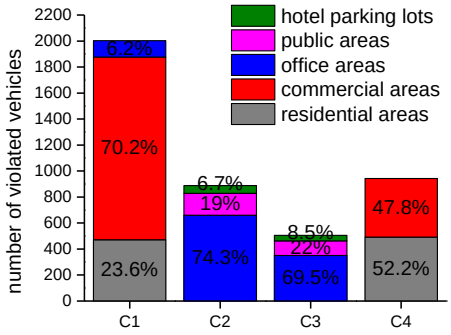



Fig. 4 Parking areas distribution of violated vehicles in each category

Figure 5 shows the parking period distribution of violated vehicles in each category, from figure 5 we can know that violated vehicles in C1 and C2 are more likely parking during day time, it is expected that due to the effect of the travel restriction policy, the number of non-local vehicles will greatly decrease in the daytime period. Violated vehicles of long parking time categories are distributed evenly in all periods while peak hours still occupy the most proportion, so the implementation of the travel restriction policy on non-local vehicles will help to reduce the traffic pressure caused by this part of vehicles during peak hours.

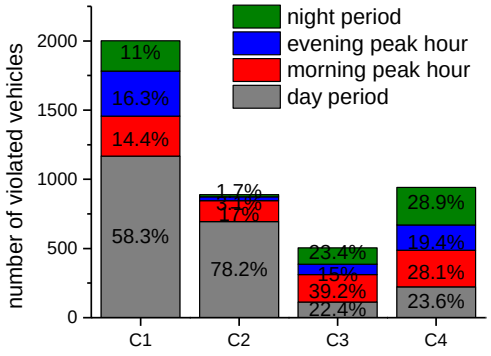



Fig. 5 Parking period distribution of violated vehicles in each category

Through the above analysis, the new travel restriction policy on non-local vehicles in Guangzhou City will have an impact on businessman who uses non-local cars for commercial activities, online cars and citizens who buy non-local cars for commuting use. The proportion of affected vehicles among all the non-local vehicles is about 19%, when this part

of vehicles has been forbidden, the demands that satisfied by this part of vehicles will decrease or shift, and thus it will result in an increase in the number of people applying local licenses and the increase in operating costs for businessman in Guangzhou City, in addition, there may be more pressure on public transport system since the citizens who used non-local vehicles for commuting may turn to public transport means, at the same time, the traffic congestion may ease since the direct decrease in the number of non-local vehicles.

## CONCLUSIONS

Based on K-means algorithm, parking behaviour characteristics of non-local vehicles have been analysed, the results show that there are 4 parking patterns for non-local vehicles in Guangzhou, and 19% of non-local vehicles are for local use. Local-use non-local vehicles are mainly used for business and commuting. The new travel restriction policy on non-local vehicles may have an impact on socio-economic activities to some extend in Guangzhou City. The conclusions from this article can provide a new perspective for the researches on vehicles behaviour and can also provide data supply for precisely managing non-local vehicles.

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