Investigation and Research on the Characteristics of Actual Activity Level of Vehicles on Typical Roads in Tianjin

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Abstract: The real vehicle activity characteristics (the traffic volume, speed and fleet composition) of typical roads (express roads, artery roads, secondary roads, and local roads) and typical districts (central city and outer suburb) in Tianjin were recorded and analyzed with a method of field investigation. the traffic volume, speed and fleet composition of volume vehicles could provide data support for vehicle emission research, targeted control and precise governance.

1. Introduction

With the development of social economy, the number of volume vehicles and mileage in Tianjin was increasing rapidly. The contribution of volume vehicle emissions in urban air pollution was increasing, which seriously affected air quality and human health [1].

In addition to the vehicle performance, fuel type and post-treatment technology, the vehicle emission in road network was closely related to vehicular activity level on the actual roads (traffic flow characteristics). But the research on the traffic condition of Tianjin local road network for the purpose of vehicle emission accounting was relatively less and earlier. In 2000, Cui et al. investigated the traffic flow of Tianjin's "Three Ring Roads and fourteen Radial Roads" and some secondary roads, and analyzed the vehicle volume and vehicle type distribution in the urban area [2]. Ye et al. conducted a field survey on volume vehicles on the road in Tianjin in 2006, and obtained a certain sample of volume vehicle information and conducted statistics and analysis [3].

However, due to the continuous improvement of vehicle environmental protection control measures in recent years, as well as the renewal of urban functional zoning and the expansion of road construction, the current road traffic situation in Tianjin, especially the traffic volume, speed, fleet composition and other important traffic parameters used for accurate calculation of vehicle emission in the whole road network had changed greatly compared with the past [4]. Therefore, it was of great significance to carry out the research on the characteristics of the actual activity level of the current road volume vehicles for the scientific evaluation of the current situation of the vehicle pollution in Tianjin.

Based on the input requirements of high spatial-temporal resolution traffic data in the HTVSE Vehicle Emission Inventory System developed by Nankai University and successfully applied in many cities in China[1,5], this study conducted field investigation and statistical analysis on the characteristics of actual vehicle activity level in typical areas and roads in Tianjin combined with local road traffic planning, in order to provide data basis for local vehicle emission inventory development, air quality assessment in sensitive areas, traffic optimization in key areas, and evaluation of volume vehicle pollution control policy effect.

2. Methodology

2.1. Research Area

Due to the large number of roads in Tianjin, it was difficult to measure each road. According to the preliminary calculation results of Tianjin volume vehicle emission inventory obtained by Zhang et al., the emission of volume vehicle pollutants in Tianjin was mainly concentrated in the central urban area and the central towns of each district [6]. Therefore, considering the urban functional zoning, road characteristics, on-site monitoring conditions, distribution characteristics of volume vehicle pollutants and control demand in Tianjin, the typical express roads, artery roads, secondary roads, and local roads in the central urban area, and the typical artery roads and secondary roads in the outer suburb (Dagang, formerly Dagang District of Tianjin, is now Dagang street, Binhai New Area, Tianjin. As an outer suburb, its road planning and traffic characteristics have strong representativeness) were selected for on-site monitoring. The area of field monitoring of vehicle activity level is shown as Figure. 1.

Figure 1: This caption has one line so it is centered.

2.2. Investigation Method

In order to obtain representative data, field monitoring was carried out on 16 typical roads in typical areas in 2019. The roads and sites information of field monitoring of vehicle activity level are shown in Table 1. Each road was continuously monitored for 7 days (including 5 weekdays and 2 weekends). The daily monitoring period was 6:00—24:00 (18 hours per day, covering rush hours and non-rush hours). The monitoring indexes included traffic volume, traffic speed and traffic fleet composition [7]. Vehicles were divided into 14 types — MIDV (mini-duty vehicle, MIDV), LDV (light-duty vehicle, LDV), MDV (middle-duty vehicle, MDV), HDV (heavy-duty vehicle, HDV); MIDT (mini-duty truck, MIDT), LDT (light-duty truck, LDT), MDT (middle-duty truck, MDT), HDT (heavy-duty truck, HDT); Bus, Taxi (Special control should be carried out); MC (Motorcycle, MC), MP (Moped, MP); TWT (three-wheel truck, TWT), LST (low-speed truck, LST).

The monitoring instruments included AxleLight RLU11 roadside traffic survey laser meter, UMRR multi-lanes speed measuring radar instrument, Hi-Pro MTC10 vehicle counter, Video recorder, etc. According to the actual conditions, these instruments were arranged on the roadsides without shelter or on the traffic gantries in the roads. The monitoring results of each instrument were compared and corrected comprehensively.

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ID	Area types	Road names	Road types	Monitoring sites
1	Central city	Waihuanxi Rd.	Express road	117.201887°E, 39.043879°N
2	Central city	Jianyang Rd.	Express road	117.13895°E, 39.116794°N
3	Central city	Fukang Rd.	Artery road	117.170064°E, 39.105501°N
4	Central city	Qufu Rd.	Artery road	117.218861°E, 39.122228°N
5	Central city	Baidi Rd.	Secondary road	117.162547°E, 39.114584°N
6	Central city	Zhangzizhong Rd.	Secondary road	117.213173°E, 39.138197°N
7	Central city	Anshanxi Rd.	Secondary road	117.186236°E, 39.120109°N
8	Central city	Hebei Rd.	Local road	117.196749°E, 39.13367°N
9	Central city	Chifeng Rd.	Local road	117.219336°E, 39.137243°N
10	Central city	Chengdu Rd.	Local road	117.213897°E, 39.12293°N
11	Outer suburb (Dagang)	Xuefu Rd.	Artery road	117.477896°E, 38.864697°N
12	Outer suburb (Dagang)	Xihuan Rd.	Artery road	117.443707°E, 38.855718°N
13	Outer suburb (Dagang)	Donghuan Rd.	Artery road	117.494948°E, 38.837892°N
14	Outer suburb (Dagang)	Shiji Rd.	Artery road	117.495586°E, 38.852281°N
15	Outer suburb (Dagang)	Nanhuan Rd.	Artery road	117.494858°E, 38.837885°N
16	Outer suburb (Dagang)	Yingbin Rd.	Secondary road	117.467995°E, 38.842958°N

2.3. Analysis Method

According to the statistical yearbook and survey results, the composition and mileage of various types of volume vehicles in Tianjin were analyzed. On this basis, combined with the field monitoring results, the traffic volume, speed and fleet composition characteristics of typical roads were further analyzed.

3. Results and Discussions

3.1. Vehicle Ownership

By the end of 2019, the vehicle population in Tianjin reached 3.09 million. The population of different types of vehicles and their proportion in 2019 are shown in Figure. 2 respectively. According to usage and sizes, the proportion of LDV was the highest (85.22%), followed by LDT (8.09%) and HDT (2.10%). According to the fuel types, most of the vehicles are gasoline vehicles, accounting for 90.47%, followed by diesel vehicles (8.55%), and the other-fuel vehicles (e.g. compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), etc.)

was precious few with a proportion of 0.98%. CHN IV vehicles were the mainstream type of all gasoline vehicles with a proportion up to 46.90%, followed by CHN V (19.16%) and CHN III (18.48%); while CHN III (5.01%) and CHN IV (2.64%) vehicles were the mainstream types of all diesel vehicles. With the implementation of the CHN V emission standard in Tianjin and the continuous promotion of old car elimination, the proportion of CHN V gasoline vehicles would be further improved, while the gasoline vehicles of pre-CHN III would be rapidly reduced.

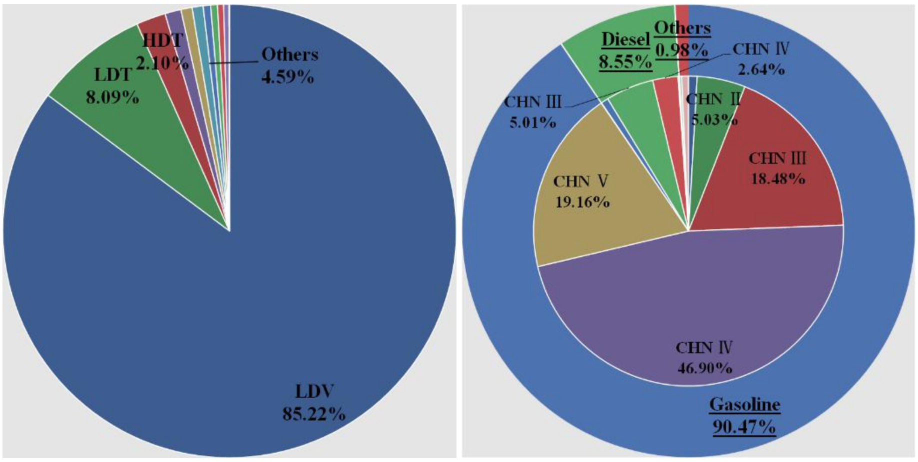


Figure 2: The proportion of different types of vehicles in Tianjin in 2019.

3.2. Vehicle Traveled Kilometer

The annual average VKT (vehicle traveled kilometer) of different types of single vehicles in Tianjin is shown as Figure. 3. The annual average VKT of Taxi was the highest (1.28×105 km), followed by HDT (7.86×104 km), Bus (6.51×104 km) and HDV (5.54×104 km). The total annual average VKT of different types of vehicles in Tianjin is shown as Figure. 4. Due to the huge amount, the total annual VKT of LDV was much higher than that of other vehicles, up to 4.53×1010 km, followed by LDT (7.00×109 km), HDT (4.21×109 km) and Taxi (4.01×109 km).

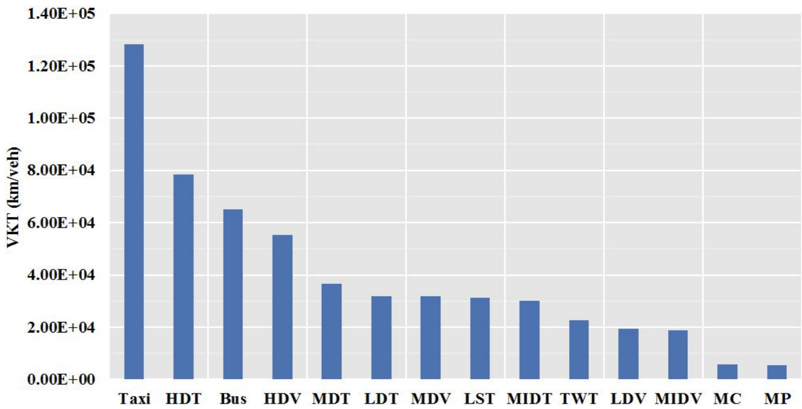


Figure 3: The annual average VKT of different types of single vehicles in Tianjin.

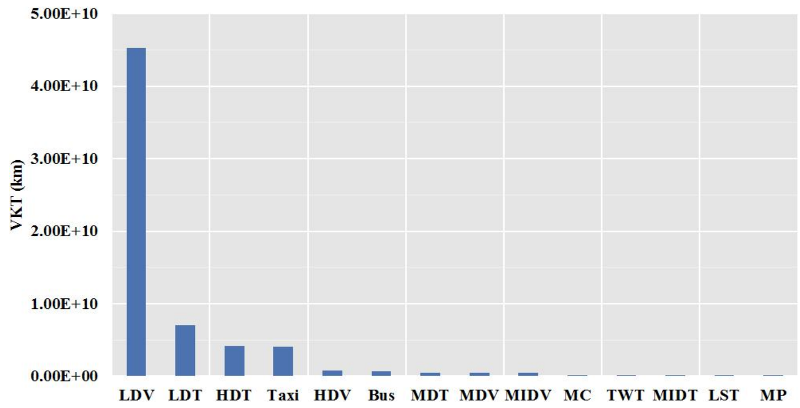


Figure 4: The total annual average VKT of different types of vehicles in Tianjin.

The spatial distribution of daily VKT in Tianjin is shown as Figure. 5. The vehicle activity intensity in Central city and Binhai (Core) was the highest, because the two regions had large population and dense road network. In addition, vehicle activity in central towns of other districts was also relatively concentrated.

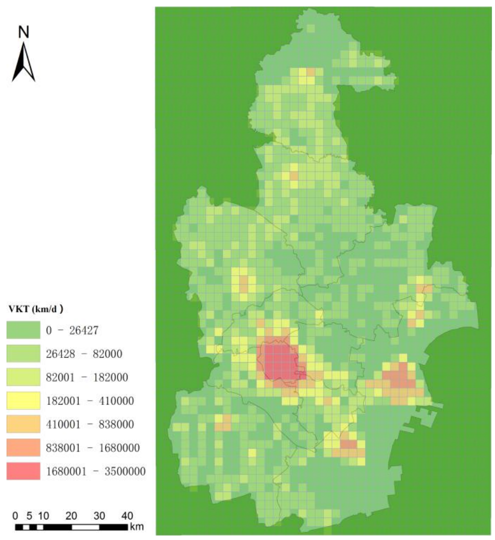
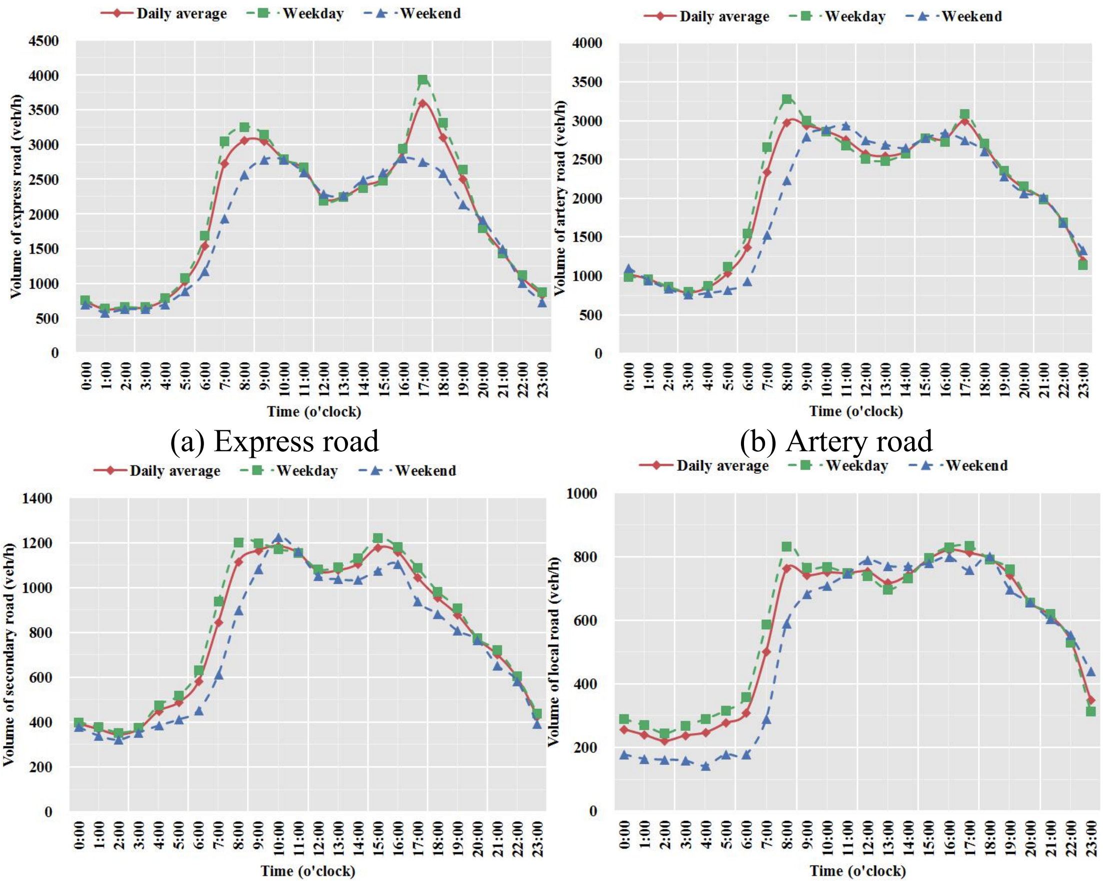


Figure 5: The spatial distribution of daily VKT in Tianjin.

3.3. Traffic Volume

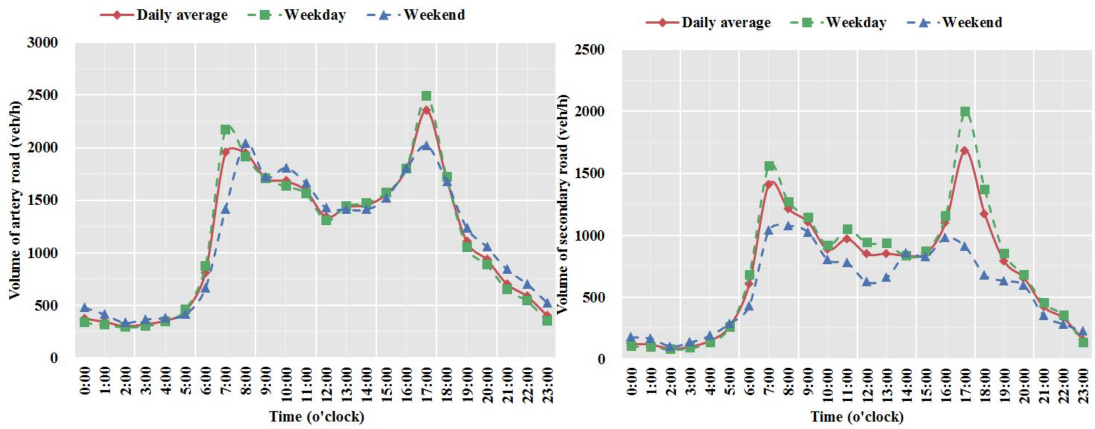
The traffic volume characteristics of different types of roads in urban area and outer suburb of Tianjin are shown as Figure. 6 and Figure. 7 respectively. The change trend of traffic volume of different types in different areas showed a distinct "M" feature, that was, there were two peak values of traffic volume every day — the morning rush hours (7:00—9:00) and the evening rush hours (17:00—19:00), which was consistent with people's daily travel rules. The peak traffic volume value of the morning rush hours of weekend appeared about one hour later than that of weekday, while the peak traffic volume value of the evening rush hours of weekend appeared about one hour earlier than that of weekday. The average daily traffic volume of weekday was generally higher than that of weekend.



(a) Express road (b) Artery road

(c) Secondary road (d) Local road

Figure 6: The traffic volume characteristics of different types of roads in urban area.



(a) Artery road (b) Secondary road

Figure 7: The traffic volume characteristics of different types of roads in outer suburb.

The daily average traffic volume of different types of roads in different areas in Tianjin is shown as Figure. 8. The traffic volume of the same type of road in the urban area was higher than that of the outer suburb, indicating that the vehicle activity in the urban area was more frequent, which was due to the large amount of vehicle and the relatively developed production and living activities in the urban area. For the urban area, the daily average traffic volume of artery road was the highest, up to 49 672 veh/d, followed by express road (46 973 veh/d), secondary road (19 564 veh/d) and local road (13 762 veh/d). For the outer suburb, the daily average traffic volume of artery road was 27 174 veh/d and obviously higher than that of secondary road (16 776 veh/d).

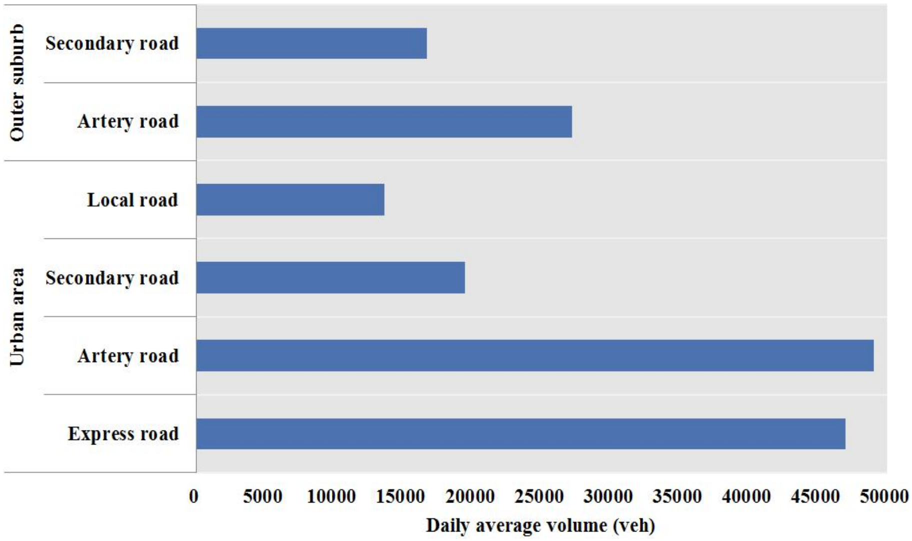
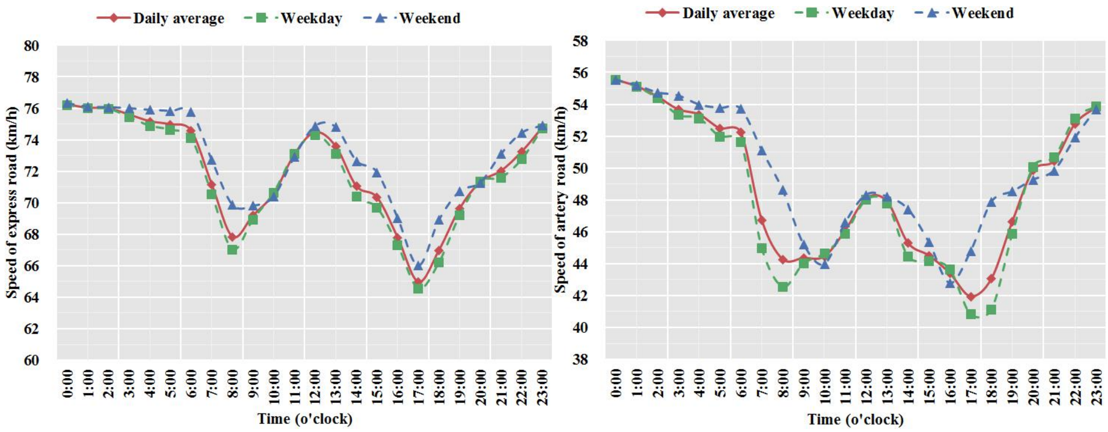


Figure 8: The daily average traffic volume of different types of roads in different areas.

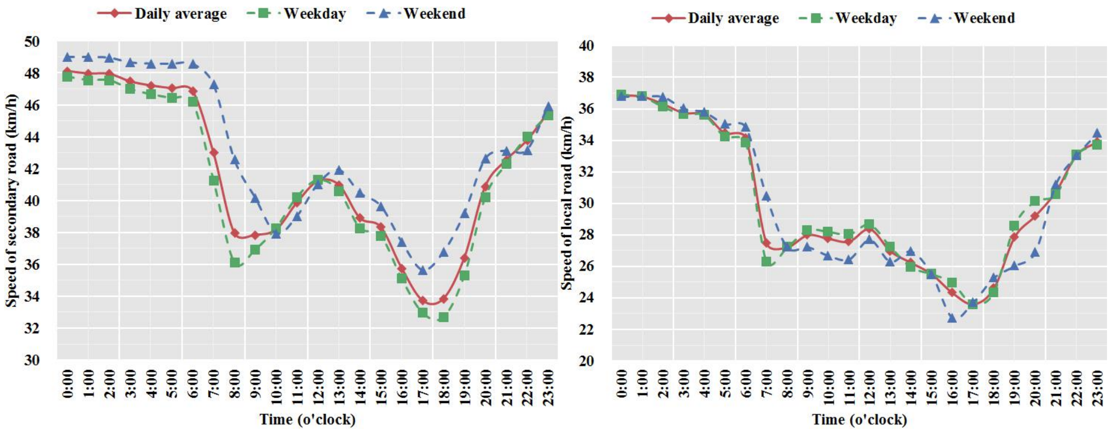
3.4. Traffic Speed

The traffic speed characteristics of different types of roads in urban area and outer suburb of Tianjin are shown as Figure. 9 and Figure. 10 respectively. The change trend of traffic speed of different types in different areas showed a distinct "W" feature, that was, there were two valley values of traffic speed every day — the morning rush hours (7:00—9:00) and the evening rush hours (17:00—19:00), which was corresponding to the change trend of traffic volume and consistent with people's daily travel rules. The valley traffic speed value of the morning rush hours of weekend appeared about one hour later than that of weekday, while the valley traffic speed value of the evening rush hours of weekend appeared about one hour earlier than that of weekday. The average daily traffic speed of weekday was generally lower than that of weekend.



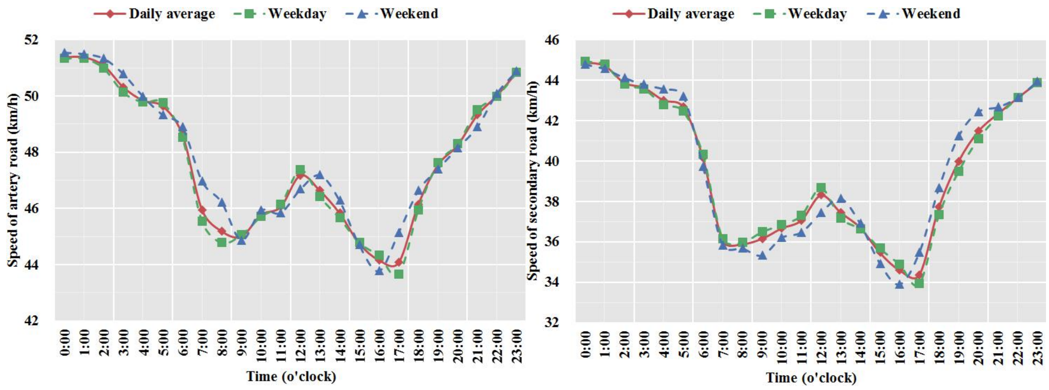
(a) Express road

(b) Artery road



(c) Secondary road (d) Local road

Figure 9: The traffic speed characteristics of different types of roads in urban area.



(a) Artery road (b) Secondary road

Figure 10: The traffic speed characteristics of different types of roads in outer suburb.

The daily average traffic speed of different types of roads in different areas in Tianjin is shown as Figure. 11. The traffic speed of the same type of road in the urban area was approximately equal to that of the outer suburb, which was related to the speed limit and the capacity of different types of roads themselves. The average daily speed of all types of roads decreased gradually according to the grade of roads. For the urban area, the daily average traffic speeds of express road, artery road, secondary road and local road were 69.24 km/h, 44.58 km/h, 39.87 km/h and 30.12 km/h respectively. For the outer suburb, the daily average traffic speeds of artery road and secondary road were 43.97 km/h and 37.94 km/h respectively. During the rush hours of the monitoring period, the vehicle was usually in the driving state of frequent acceleration, deceleration and idling. Especially on the relatively narrow and dense secondary road and local road, the vehicle's speed was relatively lower, resulting in the increase of CO, HC, PM and other pollutants, as well as the concentration of population and poor air mobility on both sides of the road, so that the pollution had more obvious and direct impact on human's health.

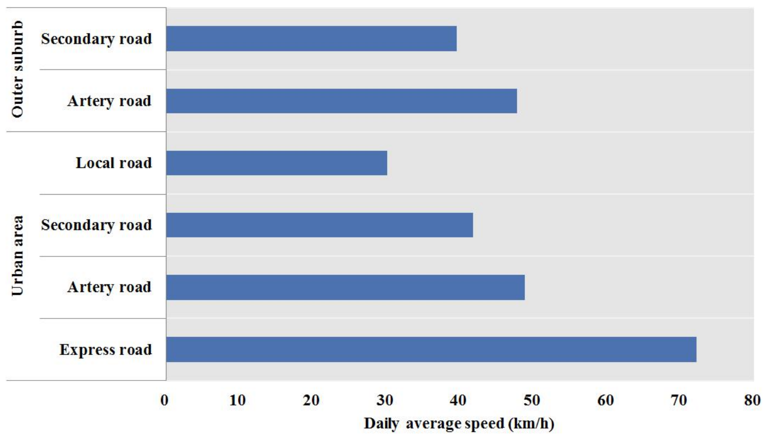


Figure 11: The daily average traffic speed of different types of roads in different areas.

3.5. Traffic Fleet Composition

The average traffic fleet composition of different types of roads in Tianjin is shown as Figure. 12 and Figure. 13. Although there were great differences in the traffic fleet composition in different types of roads and areas in Tianjin, LDV was still the mainstream type of vehicle on all types of roads, up to 80%, and the proportion of truck and MC was relatively smaller. For the urban area, truck on express road, LDV on artery road, Bus on secondary road, and Taxi on local road accounted for 4.74%, 94.68%, 7.03%, and 9.24% respectively, which were the respective highest proportion for the same type of vehicle on each kind of road, and this phenomenon was also consistent with the service features of different types of roads. Due to the difference on the regional function and the restriction policy of the truck, the proportion of truck in the outer suburb was much higher than that in the urban area; especially for the artery road in the outer suburb, the proportion of truck was 14.60%, which would increase the emission of NOx and PM.

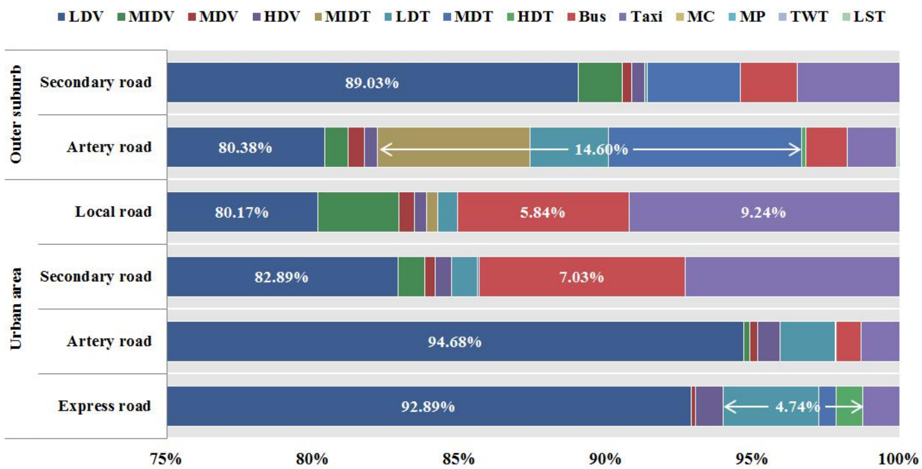


Figure 12: The average traffic fleet composition of different types of roads in different areas.

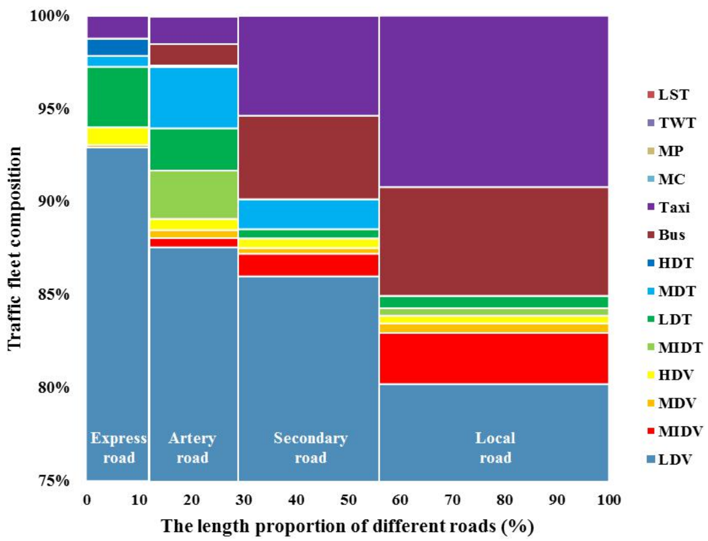


Figure 13: The average traffic fleet composition of different types of roads in whole Tianjin.

4. Conclusions

The real vehicle activity characteristics of typical roads (express roads, artery roads, secondary roads, and local roads) and typical districts (central city and outer suburb) in Tianjin were recorded and analyzed with a method of field investigation. The variation trends of hourly traffic volume and speed of each road showed the characteristics of relatively obvious "M" and "W" curves respectively, which were coincidence with people's regular daily travel pattern. The traffic volumes of the central city were much higher than that of the same types of roads of the outer suburb, while the speeds were approximately equal. The traffic fleet compositions of different types of roads had great differences, but the light-duty vehicles were still the mainstream of all roads with a proportion of more than 80%, and the proportion of trucks of the outer suburb was higher than that of the central city. The above actual activity levels of volume vehicles could provide data support for vehicle emission research, targeted control and precise governance.

Acknowledgments

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References

[1] Zhang Y, Wu L, Zou C, et al Development and application of urban high temporal-spatial resolution vehicle emission inventory model and decision support system[J]. Environmental Modeling & Assessment, 2017, 22(5):1-14.

[2] Cui J, Ding G, Xiong X, et al Investigation and Analysis of Traffic Flow in Tianjin [J]. Urban Environment& Urban Ecology, 2003(6):86-88.

[3] Ye S, Wang Q, He X Investigation and Research on the Activity Level of Motor Vehicles on the Road in Tianjin[J]. Journal of Beijing Technology and Business University (Natural Science Edition), 2007, 25(2):28-31.
[4] Tong Y, Bai H, Chen X Establishment of vehicle pollutant emissions inventory based on EMIT model: pilot study in main roads of Tianjin urban[J]. Environmental pollution and prevention, 2014, 36(1):64-68,91.
[5] Jing B, Wu L, Mao H, et al Development of a vehicle emission inventory with high temporal-spatial resolution based on NRT traffic data and its impact on air pollution in Beijing - Part 1: development and evaluation of vehicle emission inventory[J]. Atmospheric Chemistry and Physics, 2016, 16(5):3161-3170.
[6] Zhang Y, Wu L, Mao H, et al Research on Vehicle Emission Inventory and Its Management Strategies in Tianjin[J]. Journal of Nankai University (Natural Science Edition), 2017(1).
[7] Ministry of Environmental Protection. China Motor Vehicle Environmental Management Annual Report[R]. Beijing: Ministry of Environmental Protection, 2016.