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Construction and Analysis of the Dalian Driving Cycle

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Abstract

The actual driving data of Dalian city is collected by GPS devices and divided into kinematics sequences. After characteristic parameters of the kinematics sequences are calculated, this paper makes component analysis and cluster analysis to extract the representative driving data. The driving cycle of Dalian is constructed based on the analysis result of the representative driving data. The driving cycle of Dalian is compared with the driving cycles of Zhuzhou city and Chinese typical city. Comparison result shows that Dalian driving cycle is crowded.

Keywords: *electric bus; driving cycle; principal component analysis; cluster analysis*

1. Introduction

Electric bus has been more and more used in public traffic for the bus is zero release. While electric bus isn't a mature technology, lots of studies focus on electric bus. As the study basis of electric bus operation [1], driving cycle is also an important study point. Recently, some driving cycles have been constructed in Chinese city. For example Hefei city driving cycle is constructed with different statistical methods [2-5]. The construction methods of driving cycle are multifarious. The most common method is principal component analysis and cluster analysis method [6]. As driving cycle is a stochastic process, Markov process analysis is also commonly used in construction of driving cycle [7-8]. Genetic algorithm is also used in construction process and the calculation process is simplified [9]. In analysis process, the characteristic parameters have significant influence on construction result. Beside conventional parameters researcher also uses vehicle-specific power (VSP) in construction process [10].

As a significant city of China, Dalian has lot of electric buses, but the studies of Dalian driving cycle are less. This paper collects actual driving data in Dalian, divides driving data into kinematics sequences, and uses component analysis and cluster analysis method to construct the representative driving cycle of Dalian. The constructed driving cycle is compared with other common driving cycle. The constructed driving cycle can be used in study of electric bus in Dalian.

2. Data Collection and Pretreatment

To veritably make representative driving cycle, this paper uses GPS device that can record speed message with the frequency of 1Hz. During the collection process, researcher brought the device as a normal passenger to avoid influencing the driver. The bus line of data collection is line no.19 because the bus in this line is electric bus. This line starts from Huanan Square and end in Zhongshan Square. The total length is 14.5km with 17 stations. The no.19 bus line is shown in Figure 1.

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Figure 1. Bus Lines in Data Collection

The collected data is divided into kinematics sequences after abnormal data is removed. The kinematics fragment starts from one idle period and ends in next idle period. The characteristic parameters of kinematics sequences are shown in Table 1. The characteristic parameter results are used in Principal component analysis.

Table 1. Characteristic Parameters

Characteristic Parameter	Explain	Characteristic Parameter	Explain
a_a (s)	acceleration time ($a>0.1m/s^2$)	V_a (km/h)	average speed
a_d (s)	deceleration time ($a<-0.1m/s^2$)	a_{am} (m/s^2)	maximum acceleration speed
a_c (s)	cruise time ($-0.1m/s^2 \leq a \leq 0.1m/s^2$)	a_{aa} (m/s^2)	average acceleration speed
a_i (s)	idle time	a_{dm} (m/s^2)	maximum deceleration speed
S (km)	travel distance	a_{da} (m/s^2)	average deceleration speed
V_m (km/h)	maximum speed		

3. Principal Component Analysis

As shown in Table 1, there are 11 characteristic parameters and none of these parameters can independently reflect the traffic condition. Some parameters are related to others. Principal component analysis combines original variables and makes one or some comprehensive variables that can stand for the original variables. To confirm the number of new variables, the principal component cumulative proportions are calculated by math software. The result is shown in Table 2.

Table 2. Principal Component Proportions and Cumulative Proportions of Characteristic Parameters

Characteristic Value	Difference Value	Principal Component	Principal Component Cumulative Proportions(%)

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		Proportions(%)	
5.03	2.79	45.81	45.81
2.24	0.72	20.43	66.24
1.52	0.65	13.84	80.08
0.86	0.31	7.86	87.94
0.55	0.22	5.04	92.98
0.32	0.07	2.99	95.97
0.25	0.16	2.32	98.29
0.09	0.04	0.83	99.12
0.05	0.01	0.47	99.59
0.03	0.02	0.32	99.91
0.01		0.09	100

The first four principal component cumulative proportions are 87.94%, beyond 80%, so the first four principal components can stand for the characteristics parameters. The principal component values of every kinematics sequence are calculated by principal component analysis software and used in cluster analysis.

4. Cluster Analysis

The principal component analysis change the parameters form 11 to 4, the kinematics sequences should be classified. Cluster analysis is a classify method that can analyze multi-dimensional variable. The common cluster analysis methods are system clustering method, decomposition method, join method, dynamic clustering method, overlap clustering method, and fuzzy clustering method. This paper uses K-means clustering method. The clustering result divides the kinematics sequences into three categories. The average characteristic parameters of each category are shown in Table 3.

Table 3. Average Characteristic Parameters of Different Categories

	Low Speed	Middle Speed	High Speed
a_a (s)	11	24.36	35.61
a_d (s)	10.16	23.81	33.15
a_c (S)	1.17	8.18	13.84
a_i (S)	61.17	28.63	22.30
S (km)	0.10	0.27	0.55
V_m (km/h)	23.67	31	39
V_a (km/h)	5.04	11.56	18.78
a_{am} (m/s^2)	1.39	1.69	1.58
a_{aa} (m/s^2)	0.75	0.69	0.6
a_{dm} (m/s^2)	-1.8	-1.79	-1.79
a_{da} (m/s^2)	-0.89	-0.71	-0.69

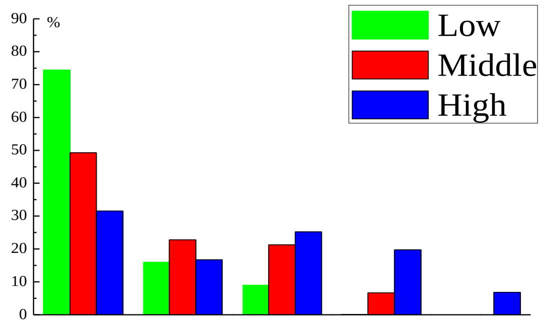

Figure 2. Speed Distribution of Different Categories

Figure 2 shows the speed distribution of different categories and figure 3 is the driving conditions distribution. In low speed condition, 74.46% of speed is below 10km/h and idle time proportion is 65.13%. In middle speed condition, 72.04% of speed is below 20km/h and idle time proportion is 35.39%. In high speed condition, 6.8% of speed is beyond 40km/h and idle time proportion is 21.79%.

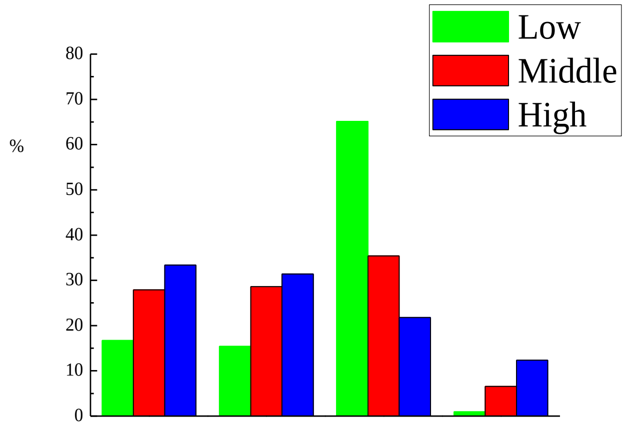

Figure 3. Driving Conditions Distribution of Different Categories

5. Construction and Analysis of Driving Cycle

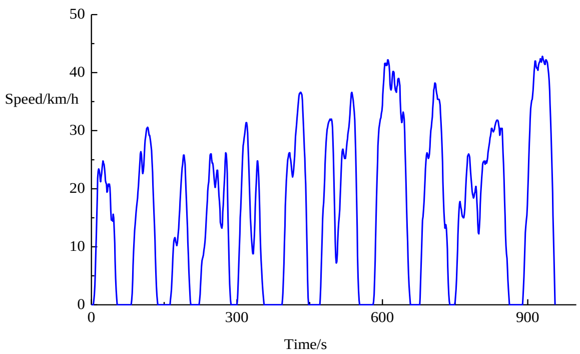

Figure 4.Time Speed Curve of Dalian Driving Cycle

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According cluster analysis result, the representative driving data of different categories are selected based on the correlation coefficient. The construction result is shown in Figure 4. The characteristic parameters of Dalian driving cycle are shown in Table 4.

Table 4. Characteristic Parameters of Dalian Driving Cycle

Dalian Driving cycle			
Time (s)	957	$P_{0\text{-}10km/h}$	37.33%
a_a (s)	294	$P_{10\text{-}20km/h}$	18.07%
a_d (s)	271	$P_{20\text{-}30km/h}$	23.92%
a_c (s)	106	$P_{30\text{-}40km/h}$	15.98%
a_i (s)	285	$P_{40\text{-}50km/h}$	4.7%
S (km)	4.37	$P_{50\text{-}60km/h}$	0
V_m (km/h)	44	P_a (acceleration time)	30.72%
V_a (km/h)	16.43	P_d (deceleration time)	28.32%
a_{am} (m/s^2)	1.94	P_i (idle time)	29.78%
a_{aa} (m/s^2)	0.61	P_c (cruise time)	11.18%
a_{dm} (m/s^2)	-2.78		
a_{da} (m/s^2)	-0.69		

According to the characteristic parameters of Dalian driving cycle, the traffic condition of this line is bad. The average speed is 16.43 km/h and the maximum speed is 44 km/h. 55.4% of speed is below 20 km/h. The idle proportion is 29.78% and cruise time is 11.18%.

To more clearly reflect the driving cycle of Dalian, the constructed driving cycle is compared with the common driving cycle of Zhuzhou city and Chinese typical city. As is shown in Table 5, the average speed of Dalian driving cycle is less than that of Zhuzhou city and higher than that of Chinese typical city. The idle time proportion of Dalian city is near that of Chinese typical city, 28.76%. And Zhuzhou city has the minimum idle time proportion, 12.6%.

Table 5. Characteristic Parameters of Different Driving Cycles in Comparison

	Dalian	Zhuzhou city	Chinese typical city
Time (s)	957	2011	1304
a_a (s)	294	735	414
a_d (s)	271	506	289
a_c (s)	106	515	225
a_i (s)	285	254	375
S (km)	4.37	10.56	5.83
V_m (km/h)	44	50.55	60
V_a (km/h)	16.43	18.9	16.1
a_{am} (m/s^2)	1.94	1.26	1.25
a_{aa} (m/s^2)	0.61	0.36	0.37
a_{dm} (m/s^2)	-2.78	-2.75	-2.48
a_{da} (m/s^2)	-0.69	-0.53	-0.53

6. Conclusions

The actual driving data is collected by GPS devices and divided into kinematics sequences. The characteristic parameters of kinematics sequences are calculated and the representative driving cycle is constructed by component analysis and cluster analysis.

The constructed driving cycle is compared with Zhuzhou city and Chinese typical city. The comparison result shows that, the average speed and idle time proportion of Dalian city are near that of Chinese city, the idle time proportion of Dalian city is higher than that of Zhuzhou city. It means that, for research with driving cycle in different city, it is better to use the local driving cycle to obtain more accurate analysis result.

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