

Research on relationship model between fuel consumption of transportation vehicles and speed in region of Hohhot

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Abstract. What enterprises concern about is the fuel consumption of trucks which is emphasis. During practical operation, the most important factors which influence the fuel consumption of trucks are characteristics parameters of vehicle working condition and characteristics parameters of vehicle running. This paper selects road transportation vehicles in three typical cities——Chifeng, Baotou and Wuhai in region of Hohhot as object of research, to investigate and calculate isochronal data and survey the questionnaire in consumption of road transportation vehicles, summarizes characteristics parameters of vehicle working condition, builds the relationship model between fuel consumption of trucks and characteristics parameters of vehicle working condition, verification result indicates that the relationship model which is built can more correctly reflect the practical fuel consumption of transportation vehicles in Inner Mongolia, error rate is $\pm 9.86\%$, By the point of view of the fuel consumption, come up with reasonable advice for selecting vehicle types and updating of road transportation vehicles, and follow up on helping vehicles to make decreasing fuel consumption come true.

1. Introduction

Fuel consumption level of road transportation vehicles in region of Hohhot is higher, the mission of energy saving and emission decreasing is arduous. Inner Mongolia “ten three five” road, water way transportation improvement essentials indicates the specific target of energy conservation and emission reduction in transportation trade: Before 2020, the energy availability ratio of transportation trade will have increased obviously, carbon dioxide emission level will have increased obviously, the consumption of road trade vehicles units of freight mileage and carbon dioxide respectively will have decreased by 6.5% and 8%, green, low-carbon transportation system will have gained obvious improvement[1]; energy conservation, emission reduction, technology innovation and service system will have been whole, achievement conversion and production popularization will have proved. Supervision capability of energy saving and emission decreasing will have promoted obviously, basically form perfect transportation Energy saving, emission decreasing strategy planning system, legislations standard system, supervision organization system and statistic checking system[2]. Build on ecological civilization strategy, follow up on boosting source saving, environment friendly traffic transportation industry construction, enhance energy conservation and emission reduction, use energy economically, boost the utilization of cyclical source, enhance ecological and environmental protection, accelerate to build the traffic transportation system which makes low-carbon as



characteristic, promote the sustainable progress of traffic transportation[3].

Inner Mongolia is located in the north of the country, with a vast territory across the northern part of China. The climate is dry and cold, and the temperature varies greatly from season to season. The road conditions are complex, hills, plains, mountains, forests and some other terrain are staggered, so there are many factors that affect road transportation cost. During “ten two five” period, the whole province has completed collectively for-hire road passenger capacity, passenger mileage, freight volume, freight mileage which are respectively 850 million people, 100.03 billion man-kilometer, 5.72 billion ton and 1225.36 ton-kilometers, that are respectively 62%, 47%, 63%, 56% in comprehensive transportation system which dominates the status[4]. The consumption cost that Road freight transportation generates takes up a big proportion in road transportation industry. The energy research which faces to road freight transportation becomes an important mission. Energy consumption statistic is the basic work in promoting energy conservation and consumption reduction in the industry, collect, settle, and analyze the statistics of energy consumption of road transportation vehicles in an accurate, timely, round, systematical manner, that reflects the industry energy consumption level and energy utilization efficiency, that provides statistical information and development decision basis for macro decision-making, management, enterprise production and operation management[5]. Study adequately the special environmental and climatic characteristics of Inner Mongolia the sampling survey is carried out on the operating conditions and energy consumption of road transportation vehicles in typical regions. Based on the existing road transportation statistics, grasp the current situation of energy consumption of road transportation in Inner Mongolia summarize scientifically the energy consumption characteristics of road transportation in Inner Mongolia based on the theoretical model evaluate the energy consumption effect of road transportation vehicles, and put forward the calculation model which fits to road transportation vehicles energy statistics in Inner Mongolia that is of great significance to cooperate with autonomous region to achieve energy conservation and consumption reduction. Therefore, it provides practical decision support for the energy conservation and consumption reduction of road transportation enterprises, pay attention to the practical application of research results, put forward effective policy suggestions. And follow up on giving suggestions to promote the development of new energy and cleaning energy vehicles, enhance the training of green driving talents and informative construction[6].

2. Identify research objectives

2.1. Selecting area

According to the statistics of the transportation authority of Inner Mongolia autonomous region in 2016, the three areas with the most freight turnover in the whole province are Baotou city (55974.07 million ton-kilometers), Hohhot (3258271 million ton-kilometers), Chifeng city (2769052 million ton-kilometers), however, the regions with less freight turnover are Xingan League (7791.22 million ton-kilometers), Wuhai city (8254.43 million ton-kilometers), Ulanqab (13484.75 million). Based on the current situation, from the perspective of the whole region, covering the eastern, central and western regions, combine with the data of turnover, select Baotou, Wuhai and Chifeng as the survey area.

2.2. Select research vehicles

In the existing research, there are several kinds of freight cars: First, it is divided into two axes, three axes, four axes, five axes and six axes; Second, based on tons of the freight vehicles, it is divided into light freight cars, medium freight cars and large freight cars, such as Jia Hongfei who divides freight cars into light freight cars (<2.5 tons), medium freight cars (2.5-7 tons) and large freight cars (>7 tons) according to the weight of the vehicles. According to the statistics of the transportation authority of Inner Mongolia autonomous region in 2016, the types of vehicles in the selected areas are shown in tables 1 and 2.

Table 1. The characteristics of vehicles types.

Code	Region	large/heavy vehicles (unit)	Medium vehicles (unit)	Light vehicles (unit)
1	Baotou	16882/14516	195	14685
2	Wuhai	4468/4327	255	1443
3	Chifeng	14912/11798	1992	29307

Table 2. The characteristics of vehicles fuel.

Code	Region	Integrated vehicles (unit)			Tractor (unit)		
		gas	diesel	Other fuel	gas	diesel	Other fuel
1	Baotou	9848	9951	431	11	9242	1110
2	Wuhai	120	4684	0	34	1246	0
3	Chifeng	2038	39859	0	0	4464	6

According to the data of tables 1 and 2, it can be seen that the types of the vehicles are mainly concentrated in heavy and light vehicles, and fuel is concentrated in diesel vehicles and some gasoline vehicles. According to the national standard of automobile classification (GB9417-89), when the freight vehicles operate on the road, manufacturer's maximum total mass (GA) is divided into: mini vehicles ($GA \leq 1.8$ tons), light vehicles ($1.8 \text{ tons} < GA \leq 6$ tons), middle vehicles ($6.0 \text{ tons} < GA \leq 14$ tons), heavy vehicles ($GA > 14$ tons). Based on these points, the research vehicles in this project are concentrated in heavy vehicles, classifications are shown:

- heavy type I : $GA \geq 30$ tons
- heavy type II : $30 \text{ tons} > GA \geq 25$ tons
- heavy type III: $25 \text{ tons} > GA \geq 20$ tons
- heavy type IV: $20 \text{ tons} > GA \geq 14$ tons

Synthetically consider the characteristics of selecting region, dividing types of vehicles and fuel, finally form the table 3 which is shown.

Table 3. Vehicles selection.

code	region	Heavy vehicles (unit)				total
		heavy I	heavy II	Heavy III	heavyIV	
		gasoline/diesel/other fuel				
1	Baotou	0/4/0	0/4/0	0/4/0	0/4/0	0/16/0
	total	4	4	4	4	16
2	Wuhai	0/1/0	0/2/0	0/2/0	0/2/0	0/7/0
	total	1	2	2	2	7
3	Chifeng	0/3/0	0/3/0	0/3/0	0/4/0	0/13/0
	total	3	3	3	4	13
total						36

In current situation, heavy vehicles concentrate on diesel, therefore, diesel freight vehicles are mainly considered in the selection of heavy truck samples. Then consider the number of sampling equipment, 3-4 freight vehicles are selected for each partition. According to the need of the model construction, it is needed to select the representative freight vehicles which cover every working condition and operate in each season all around the year to collect data, transport routes are not limited, transport regions are not limited, transport conditions and grades are not limited, transport time is not limited, transport weather and terrain are not limited.

2.3. Data collection

The model I of the relationship between fuel consumption of transportation vehicles and characteristics parameters of transportation vehicle working condition and the model II of the relationship between fuel consumption of transportation vehicles and characteristics parameters of transportation vehicle running condition refer to the data of three asp: Characteristics parameters of vehicle working condition, characteristics parameters of transportation vehicle running and parameters of vehicle fuel consumption. Some of characteristics parameters of vehicle working condition and characteristics parameters of transportation vehicle running are depended on the item “Research and development of Chinese new energy vehicle products test condition—data collection in city of Hohhot” which is signed by Transportation Institute, Inner Mongolia University and China automobile technology research center to collect data (figure 1); Some of it uses funding to purchase 10 data acquisition devices which are installed on the selected vehicles, continuously collect valid data at least one year. The collected 48 parameters need to be sorted and refined, according to the need of the model construction, select some characteristics parameters of vehicle and characteristics parameters of vehicle running. And the collection of vehicle fuel consumption is completed by two ways: One is real-time track record of vehicle fuel consumption measurement device, another is the long-term track record of the questionnaire. There are many types of vehicle fuel consumption measuring devices (figure 2), considering the convenience of installation and reliability of collection, measurement equipment of type of liquid level sensor will be used. And the questionnaire survey can fully measure the running range and load change of freight vehicles, which can supply the energy consumption cost of freight vehicles in a long term.



Figure 1. Chinese working condition collection device.



Figure 2. Vehicle fuel metering device.

3. Model of fuel consumption of transportation vehicles and characteristics parameters of working condition

3.1. Deal with the data based on BEIBEN HEV vehicles

Select and deal with the standard data of Huhehaote-0044 vehicles (table 4).

Table 4. Vehicles selection.

code	Fuel consumption (L)	Fuel consumption per hundred kilometers (L/100 km)	Average velocity (Km/h)	IRI (m/km)	Longitudinal slope (%)
1	21.1736	21.1736	28.01	1.05	0.42
2	22.2574	22.2574	28.03	1.06	0.43
3	19.3860	19.3860	28.93	1.11	0.43
4	21.7920	21.7920	28.86	1.12	0.44
5	22.6876	22.6876	29.35	1.07	0.41
6	21.6832	21.6832	30.80	1.20	0.46

7	21.9420	21.9420	32.72	1.15	0.45
8	23.5256	23.5256	33.49	1.17	0.52
9	23.1252	23.1252	34.31	1.19	0.48
10	24.3178	24.3178	36.38	1.31	0.52
11	24.7970	24.7970	36.98	1.28	0.51
12	24.4430	24.4430	37.34	1.19	0.46
13	24.9080	24.9080	37.96	1.36	0.53
14	28.1062	28.1062	41.51	1.26	0.54
15	28.5916	28.5916	41.53	1.25	0.52
16	28.2892	28.2892	42.07	1.29	0.53
17	27.3344	27.3344	42.22	1.43	0.49
18	27.4892	27.4892	42.25	1.38	0.56
19	28.3676	28.3676	43.24	1.36	0.53
20	29.9234	29.9234	47.43	1.21	0.53

Select and deal with the standard data of Huhehaote-0008 vehicles (table 5).

Table 5. 0008 vehicle data processing result.

code	Fuel consumption (L)	Fuel consumption per hundred kilometers (L/100 km)	Average velocity (km/h)	IRI (m/km)	Longitudinal slope (%)
1	17.8856	17.8856	23.74	1.06	0.39
2	17.0960	17.0960	24.92	1.09	0.42
3	18.1750	18.1750	25.35	1.11	0.43
4	16.9340	16.9340	26.10	1.08	0.49
5	17.5698	17.5698	26.78	1.13	0.47
6	17.7438	17.7438	27.90	1.13	0.53
7	17.2366	17.2366	27.92	1.16	0.51
8	19.7212	19.7212	27.97	1.23	0.47
9	17.4330	17.4330	28.30	1.25	0.48
10	18.4956	18.4956	28.76	1.27	0.55
11	16.4902	16.4902	28.82	1.30	0.46
12	17.2316	17.2316	29.03	1.31	0.53
13	18.7248	18.7248	29.14	1.28	0.56
14	16.2144	16.2144	29.77	1.39	0.46
15	19.7144	19.7144	30.17	1.41	0.42
16	18.5032	18.5032	31.63	1.27	0.52
17	18.2372	18.2372	31.92	1.33	0.57
18	19.3428	19.3428	32.03	1.36	0.49
19	19.8200	19.8200	32.48	1.28	0.47
20	19.7156	19.7156	33.72	1.19	0.51

3.2. Fuel consumption - velocity basic model

Data in table 6 record the part of the running data of BEIBEN freight vehicles.

We use the average value of fuel consumption of BEIBEN freight vehicles, combine the average velocity, select and calculate (table 7). It can be shown as figure 3.

Table 6. Running data of Beiben freight vehicles.

code	Fuel consumption (L)	Fuel consumption per hundred kilometers (L/100 km)	Average velocity (km/h)	IRI (m/km)	Longitudinal slope (%)
1	21.1736	21.1736	28.01	1.05	0.42
2	22.2574	22.2574	28.03	1.06	0.43
3	19.3860	19.3860	28.93	1.11	0.43
4	21.7920	21.7920	28.86	1.12	0.44
5	22.6876	22.6876	29.35	1.07	0.41
6	21.6832	21.6832	30.80	1.20	0.46
7	21.9420	21.9420	32.72	1.15	0.45
8	23.5256	23.5256	33.49	1.17	0.52
9	23.1252	23.1252	34.31	1.19	0.48
10	24.3178	24.3178	36.38	1.31	0.52

Table 7. Velocity-average fuel consumption.

Standard velocity value (km/h)	Fuel consumption (L)
24.33	17.4908
25.73	17.5545
27.34	17.6568
27.95	18.4789
28.02	21.7155
28.53	17.9643
28.90	20.5890
28.93	16.8609
29.46	17.4696
30.08	22.1854
30.90	19.1088
31.98	18.7900
33.10	19.7678
33.12	22.7338
35.35	23.7215
37.16	24.6200
39.74	26.5071
41.80	28.4402
42.24	27.4118
45.36	29.1455

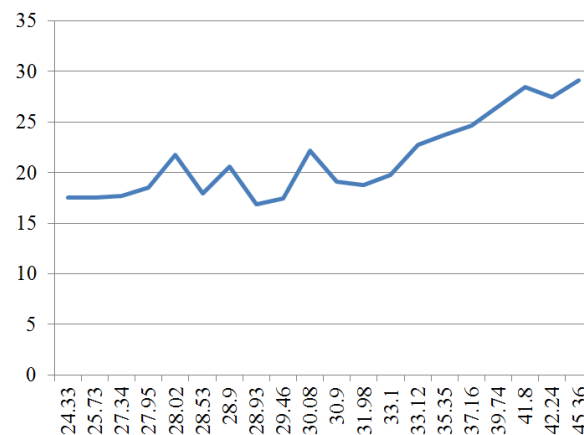


Figure 3. Relation of fuel consumption-velocity

There are two existing current basic model forms of fuel consumption-velocity.

$$F_0 = aV^2 + bV + c \quad (1)$$

$$F_0 = aV^2 + b/V + c \quad (2)$$

Where F_0 —Fuel consumption per hundred kilo-meters, V —average velocity, a — c —regression parameter.

Fit the form 1, results are shown in table 8.

Table 8. Result of fitting model.

a	b	c	R^2
0.0159	-0.7147	26.3303	0.8782

Fit the form 2, result are shown in table 9. Results are shown in table 9.

Table 9. Result of fitting model.

a	b	c	R^2
0.0079	206.645	5.2417	0.9684

According to the analysis, it indicates after assigning for flatness and Longitudinal slope, the relationship between fuel consumption and velocity presents a quadratic function, this is consistent with most previous studies, two models have high decision coefficients and same precision, the latter is more accurate, they can all be used as fuel consumption—velocity model.

4. Conclusions

In order to study the relationship between energy consumption and characteristics parameters of vehicle running in Hohhot area, this paper selects BEIBEN HEV vehicles as representative. Analyze the energy consumption under different velocity and road conditions, analyze the relationship between fuel consumption and velocity, according to the fuel data in Hohhot area, amend the model which fits the situation of our province and more accurate, that can be used to assess the energy consumption of freight vehicles of our province. What need to be pointed out is that the model calculation still exist problem that data size is not large and the vehicle is single, and the real-time weather, traffic volume and other problem are not directly considered.

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