

## Average Fuel Consumption Calculation Model of Touring Coach Based on OBD Data- A Case Study in City X

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**Abstract.** Reducing fossil fuel consumption of transportation is one of the key for energy conservation and emission reduction of every megacity. The essential data of this research came from 4 similar kinds of touring coaches including 64 vehicle trips whose cumulative operating time and mileage were 778.8 hours and 17,816 kilometers. In this research, the average fuel consumptions in different road types were figured out based on the fuel consumption calculation model. This was a case study of registered touring coaches in city X, the R-Squared of the regression equation of speed and instantaneous fuel consumption was 0.993. The accuracy of model measured from following test of other 3 vehicle trips was 91.69%. The average fuel consumption calculation model was built as theoretical foundation for optimizing vehicle distribution of passenger transportation market.

### Introduction

The fuel consumption of vehicles in developing countries contributed a lot and increased daily[1]. Based on the summarization of present literatures, the changing form of fuel consumption of different vehicle were distinct[2]. The fuel consumption was strongly correlated with properties of vehicle, such as rated passenger capacity, engine power, travelled mileage, transmissions, tyre vibration, auxiliary equipment, brakes, and so on[3]. To get the high accuracy changing rule between fuel consumption and speed, four kinds of different brand touring coaches which were similar in shape, engine power, rated passenger capacity, travelled mileage and vehicle weight were collected. Fuel consumption was also related to pavement type[4,5], so this research focused on six types of road: freeway, express way, main road, minor road, branch road, side road, which pavement type were all asphalt (AC). Because the fuel consumption of low speed is strongly related to many other factors which were not the objectives of this research and would significantly increase[6], data with speed value higher than 16 km/h and lower than design speed were specially collected. And the average fuel consumption calculation model was built by regression analysis and the accuracy of model reached 91.69%. At last, the expected values of fuel consumption in six road types were worked out.

### Fuel Consumption Data Collection

To some other factors which were not in the scope of this research, the registered touring coaches of city X in similar shape, engine power, rated passenger capacity, travelled mileage and vehicle weight but different in brand were selected. The details were shown in Table 1. As the complicated statistic process of calculating cumulative operating mileage from producing and the average operating mileage per day of each touring coach in city X were approximate, the travelled mileage parameter was replacing with registration date. Zhang[6] worked out the fuel consumptions of all kinds types of transport buses with portable emission measurement systems in Beijing. In his research, although road type was considered, the R-Squared of the model he built in which the speed of test buses were all below 60 km/h was just about 0.68.

In this research, most of test touring coaches could reach the design speed of all kinds of road types in durations.

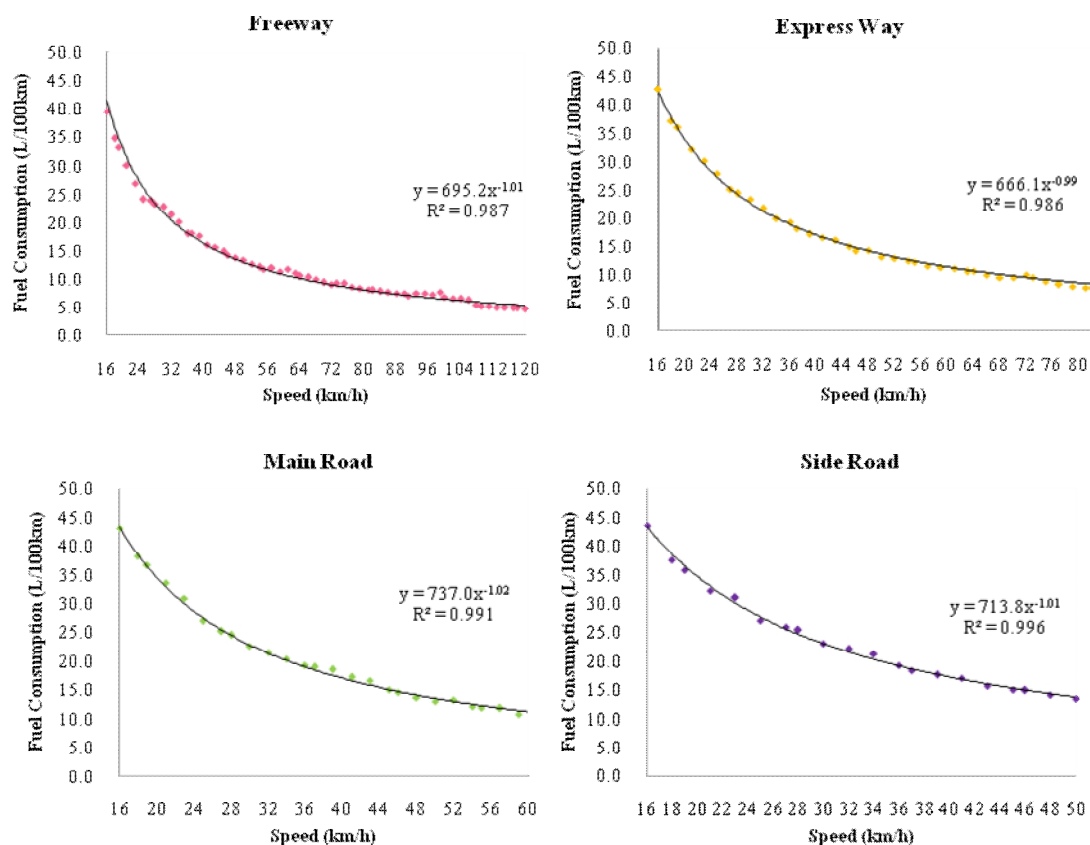
Table1. List of Vehicle Parameters

Vehicle Brand	Shape [Enclosed/ Half-Open]	Engine Power [kw]	Rated Passenger Capacity [person]	*Registration Date [MM.YYYY]	Vehicle Weight [kg]
A	Enclosed	240	50	06.2008	12900
B	Enclosed	240	50	06.2008	12900
C	Enclosed	240	50	08.2008	12900
D	Enclosed	240	50	08.2008	12900

The fields of On-Board Diagnostic(OBD) data involved vehicle basic information, track information and hourly fuel consumption information, which including recording time, license plate number, longitude, latitude, dashboard speed, instant hourly fuel consumption and road type. 4,700,000 of OBD data of 64 vehicle trips accumulating 778.8 hours was collected, the average interval of recording time were 6 seconds. The research scope of speed of six road types should be limited to avoid the influence of PnG (pulse-and-gliding which was an effective way of saving fuel by speeding up in a short time and then gliding to low speed) [7]. PnG could happen in every road type when space headway was long enough.

### Fuel Consumption Calculation Models of Six Road Types

The fuel consumption of 64 vehicle trips for every recording time interval came from instant fuel consumption and dashboard speed. The operating line of every vehicle trips were classified as freeway, express way, main road, minor road, branch road, side road. The statistical fuel consumption for every speed was the median of all instantaneous fuel consumptions. The R-Squared results of regression analysis between speed and instantaneous fuel consumption of six road types were all high than 0.98 as Fig.1 showed. So the six fitted equations had statistical significance.



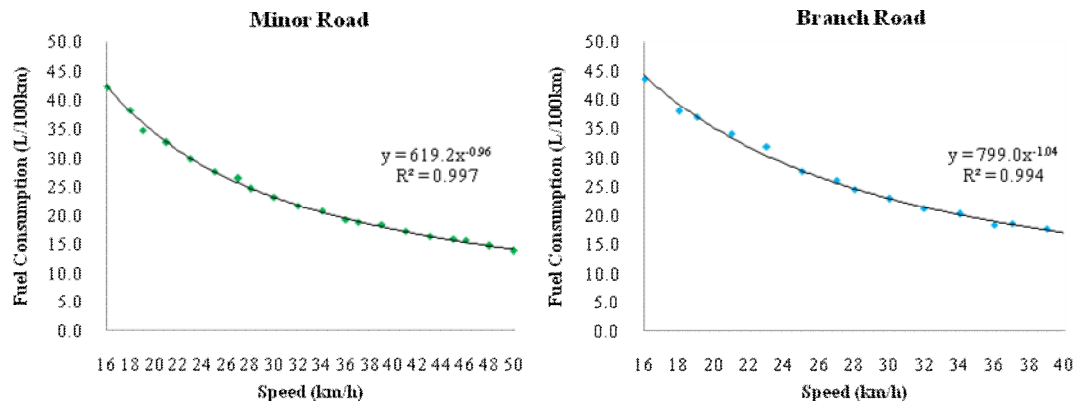


Fig.1. Correlation between Fuel Consumption and Speed for Six Road Types

According to the statistical results, the consumption of statistic fuel was from high to low. And that distribution rule had a significant influence on expected values of fuel consumption of six road types. The valid OBD data with information of operating line and fuel consumption were selected by deleting faulty data. Speed appearing rate was the percentage of the appearing times of a speed account for the quantity of recording time in whole operating time. As Fig. 2 showed, the speed appearing rate restricted the average speed of six road types, which straightly reflecting the influence of driving speed from road types. The driving speed increases as the level of road type increased.

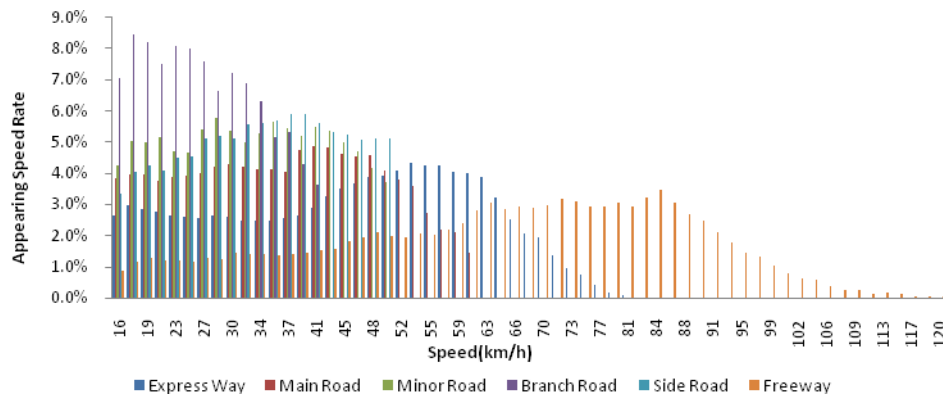


Fig.2. Speed Appearing Rate for Six Road Types

### Average Fuel Consumption Calculation Model

Average fuel consumption calculation model came from the six fuel consumption calculation models of six road types. The regularity of six fuel consumption calculation models of different road types was outstanding. The fuel consumption calculation model of city X is based on the six models. As was shown in Equation 1, the R-Squared of the fitted equation based on regression analysis of statistic fuel consumption of six road types was 0.993. So the fitted equation had statistical significance.

$$f_c = 778.5v^{-1.03} \quad (1)$$

where  $f_c$  is average fuel consumption, L/100km;  $v$  is driving speed, km/h.

As Fig. 3 showed, the variation regularity of speed and average fuel consumption followed power function distribution which declined rapidly before kept steady. The average fuel consumption of touring coaches in city X remained 7 L/100km stably while speed reached 80 km/h.

As the result, the fuel consumption of these touring coaches driving on freeway would be much lesser than on low-level road types.

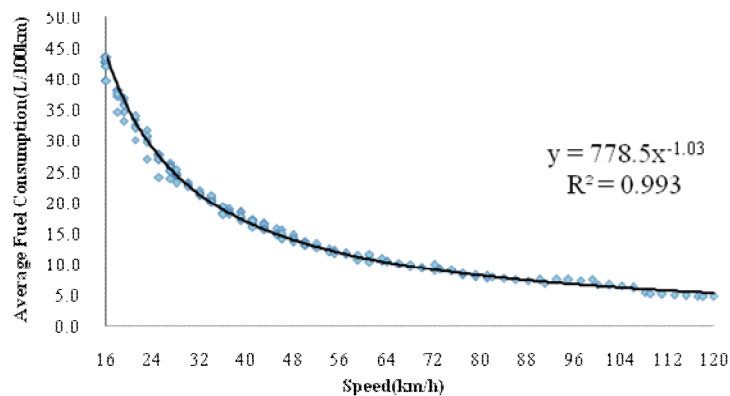


Fig.3 Correlation between Average Fuel Consumption and Speed

The new 3 vehicle trips operating data which selected from other touring coaches which was in the same type with above four kinds of touring coaches were used to verify the model accuracy. At first, the operating data were filtered in above three steps. The results of five groups T-test which were taken between every group of real fuel consumption and statistical fuel consumption reflected they were strongly related, as Table 2 showed. And the average accuracy of the model was 91.69%. So the average fuel consumption calculation model had statistical significance.

Table2. Results of Paired Samples Correlations

	N	Correlation	Sig.	Bias	Bootstrap for Correlationa		
					Std. Error	95% Confidence Interval Lower	Upper
Pair 1	59	.998	.000	.000	.001	.997	.999
Pair 2	44	.989	.000	-.001	.005	.976	.995
Pair 3	42	.958	.000	.001	.015	.928	.982

And then, the expected fuel consumptions for six road types were calculated on the average fuel consumptions and the speed appearing rate for six road types. As Fig.4 showed, the fuel consumption of freeway, express way, main road, minor road, side road and branch road respectively were 13.1L/100km, 18.3L/100km, 21.8L/100km, 24.0L/100km, 23.0L/100km and 28.3L/100km. The result of the six expected fuel consumptions were clustered in three levels: excessive level, saving and normal levels. For city X, the touring coaches driving on free way belonged to saving level; driving on express way, main road, minor road and side road belonged to normal level; driving on branch road belonged to excessive level. Obviously, this type of touring coaches in city X was more suitable for long-distance passenger transportation than serving short-distance trip.

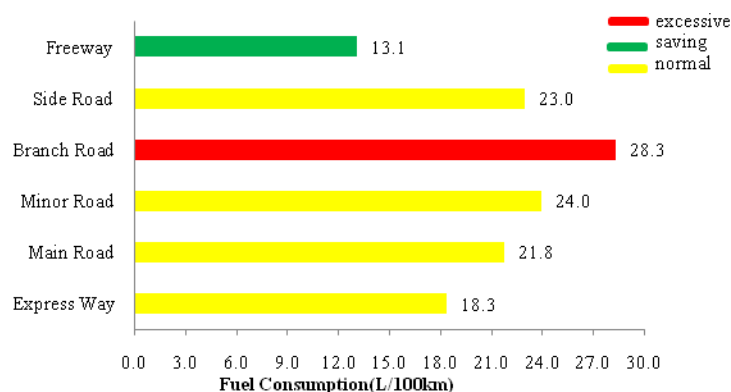


Fig.4 Expected Fuel Consumption for Six Road Types

## Conclusions

The rules for filtering 64 registered touring coaches' data were built to analyze the variation regularity of speed and fuel consumption. The fuel consumption calculation models of freeway, express way, main road, minor road, branch road and side road which R-Squared results were all high than 0.98 were built on scientific analysis. The average fuel consumption calculation model of touring coaches in city X which R-Squared result was 0.996 and accuracy reached 91.69% was built on the correlation between fuel consumption and speed for six road types. Finally, the expected fuel consumptions of six road types were reached by calculating on average fuel consumption calculation model and speed appearing rate. In conclusion, this kind of touring coaches was more suitable for long-distance passenger transportation.

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