Emission Characteristics of Heavy-Duty Diesel Transit Buses at Bus Stops in Beijing

A summary of the results from a study of the emission characteristics of transit buses at bus stops in Beijing, China
Beijing, China, the capital of the People’s Republic of China, is one of the most populous cities in the world and host to a vast public transit network. In 2011, the population of transit buses in Beijing was 21,548, which served 5.05 billion passengers. There were 713 transit lines with a total distance of 18,743 km and 1.409 billion bus-kilometers travelled." \(^1\) With such a huge population and high usage, transit buses were estimated to have contributed 25.2% of oxides of nitrogen (NO\(_x\)) and 18.2% of particulate matter (PM) in the urban area of Beijing in 2009.\(^2\) Transit bus stops are hot spots where high emission concentrations are observed and are heavily used by a large number of transit passengers. Thus, transit passengers near bus stops are directly exposed to high concentrations of pollutants. Therefore, it is essential to study and understand emission characteristics of transit buses in order to develop and evaluate effective emission control strategies for transit buses.

**Study Methodology**

In order to reflect the real-world driving and emission characteristic of transit buses, a total of 27,180 groups of valid records were collected by on-board portable global positioning satellite (GPS) devices and portable emission measurement systems (PEMS) during the morning and afternoon rush hours in Beijing (6:30–11:30 a.m. and 1:30–7:00 p.m.) on November 30, December 2, and December 8, 2010.

At bus stops, transit buses are assumed to begin entering activities or finish exiting activities within a fixed distance from stop points, which is assumed to be 50 m for each acceleration length and deceleration length separately, as shown in Figure 1.

Vehicle-specific power (VSP) is defined as the instantaneous power per unit mass of the vehicle, and VSP-bin is the discrete mode of VSP. The instantaneous power generated by the engine is used to overcome the rolling resistance and aerodynamic drag, and to increase the kinetic and potential energies of the vehicle. The existing studies have found that VSP has a close relationship with both the emission characteristic and the driving behavior.\(^3\)\(^-\)\(^5\) Therefore, an approach based on VSP distribution\(^3\)\(^-\)\(^5\) has been used for vehicle emission estimation in this research, as shown in the equation below:

\[
VSP = v \times (a + 0.09199) + 0.000169 \times v^3
\]

\[\forall : N-0.5 \leq VSP < N + 0.5\]

\[VSPBin = N\]

\[N \in [-20, 20], N \in Z\]

\[
EF = \frac{\sum ER_i \times f_i}{v}
\]

where \(v\) is the average speed (m/sec), \(a\) is the acceleration (m/sec\(^2\)), \(EF\) is the emission factor (g/m), \(i\) is the ID number of the VSP bin, \(ER_i\) is the emission rate of the VSP bin \(i\) (g/sec), and \(f_i\) is the time proportion of VSP bin \(i\) (%).

Figure 1. Definition of acceleration and deceleration segments.

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Study Results
VSP Distributions when Entering and Exiting Bus Stops
The research found that in the length-based approach, the VSP mainly distributes in the VSP bin range of -5 to 0, with the highest proportion in the VSP-bin of 0 when entering the bus stops. When exiting from bus stops, we found that the VSP mainly distributes in the range of VSP higher than or equal to 0. Besides, on the expressway, transit buses exiting the curbside stops have contributed more in the VSP bin range of 4 to 8 than in bus bays, which means that a longer aggressive accelerating mode and higher emission rates in curbside stops are observed than in bus bays. On the major arterial, however, VSP distributions in curbside stops are similar to those in bus bays. On minor arterial and collector roads, we found that transit buses in bus bays distribute more travel time in the VSP bin range of 2 to 7 than in curbside stops, as shown in Figure 2.

Emission Characteristic when Entering and Exiting Bus Stops
Our research found that emission factors for NOx, PM, hydrocarbons (HCs), carbon monoxide (CO), and carbon dioxide (CO2) of transit buses in bus bays are higher than those in curbside bus stops, except those in the curbside bus stops on minor arterial and connectors. The reason is that the driving behavior is more complicated for transit buses driving in and out from the bus bays than those directly stop and go in the curbside stops, which need not merge into the traffic flow. The relative difference of emission factors distributes at the range of 1.41% to 33.85%.

Meanwhile, by comparing entering with exiting activities, we found that emission factors of transit buses entering the bus stops are lower than those of exiting from the bus stops. However, the transit bus exhibits higher NOx, CO, and CO2 emission factors on minor arterial and connector roads and

Figure 2. VSP distributions of transit bus entering and exiting activities.
higher NOx emission factors on expressway when entering the curbside bus stops than those when exiting from the same bus stops, as shown in Figure 3.

**Summary**

Our research found that the average duration for entering bus stops is between 6 and 10 seconds, while for exiting activities, the average duration is between 5 and 8 seconds. In terms of driving characteristics, results show that when entering bus stops, the VSP distributes mostly in the VSP bins range of less than or equal to 0. However, when exiting from bus stops, it mainly distributes in the VSP bins range of higher than or equal to 0. Emission factors of NOx, HC, CO, CO2, and PM for transit buses when entering bus bays are lower than those of exiting from bus bays. However, at curbside stops, the emission factors of NOx, CO, CO2 on minor arterials and collector roads, and NOx on expressway during the entering activities are higher than those during the exiting activities.

From an emissions perspective, it is observed from our research that the bus bays are a better design option than the curbside stops option on expressways, while the curbside stops are a better design option on minor arterials and collector roads.

**References**