

Layout Methods of Monitoring Stations for Diesel Freight Trucks Emission Supervision Using Highway Traffic Survey Data—— Taking Shanxi Province as an Example

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Abstract. The in-use diesel trucks have high use intensity, high mobility, and frequent excessive emissions, which have become one of the important air pollution sources. The Action Plan for Tackling the Challenges of Diesel Truck Pollution Control issued by the Chinese government requires the establishment of a national monitoring network for transport-related air pollution and the use of various means to monitor diesel truck emissions. This study briefly summarized the requirements for diesel truck emission monitoring and supervision. Relying on the highway network traffic survey data, a method for identifying the main route of regional highway freight transportation was proposed. Then referring to the experience of highway air quality monitoring networks at home and abroad, the article proposed layout methods for roadside air quality monitoring stations, vehicle remote sensing monitoring stations, and road inspection stations, which fills the gap in domestic methods. At last, a demonstration study on the layout plan for the in-use diesel truck emissions monitoring stations in Shanxi Province was carried out. Taking Shanxi's main highway freight corridors as the key supervision area, this article screened out 44 roadside air quality monitoring stations, 24 vehicle remote sensing monitoring stations, and 15 road inspection stations.

1 Introduction

According to the China Mobile Source Environmental Management Annual Report (2019) issued by the Ministry of Ecology and Environment of China, diesel trucks that accounted for 7.9% of vehicle ownership in the whole country emitted 60.0% of nitrogen oxides (NO_x) and 84.6% Particulate matter (PM) of total vehicle emissions in 2018, which are the top priority of motor vehicle pollution prevention.

Diesel trucks are mainly commercial vehicles, with high intensity of use, harsh operating environment, and relatively high pollution emissions. They have become an important pollution source affecting the atmospheric environmental quality of many cities, and have gradually attracted widespread attention from the government and the public. At the end of 2018, the Chinese government issued documents such as the Action Plan for Tackling the Challenges of Diesel Truck Pollution Control, which clearly required the establishment of a national monitoring network for transport-related air pollution and comprehensive monitoring and supervision of diesel trucks emissions by various means. In recent years, a large number of measurements and researches have been conducted on the motor vehicles emissions, but few studies have been carried out on the layout of emission monitoring stations for diesel trucks. In order to better support the construction of transport-related air pollution monitoring network and diesel truck emissions

supervision, this study intends to focus on the identification method of highway freight corridors and the layout method of diesel truck emissions monitoring and supervision stations based on highway traffic survey data.

2 The requirements for diesel truck emission monitoring and supervision

The Action Plan for Tackling the Challenges of Diesel Truck Pollution Control proposed: ① Establish a national monitoring network for transport-related air pollution, build air quality monitoring stations in major coastal and inland ports and important freight corridors completed by the end of 2020; ② Take main highway freight corridors as the key supervision area, and use motor vehicle remote sensing monitoring, networking of emission inspection agencies, heavy-duty diesel truck On-Board Diagnostics (OBD) monitoring, road and site inspections to carry out a full range of diesel truck emission monitoring and supervision; ③ Speed up the construction of remote sensing monitoring capabilities for motor vehicles, and build remote sensing monitoring stations on major roads where diesel vehicles pass according to work needs; ④ Conduct regular road inspections on diesel vehicles in key sections of each city.

The Outline of Ecological Environment Monitoring Planning (2020-2035) proposed: Promote the construction of roadside air quality monitoring stations along the main

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road in the cities and the national highways across the country, and monitor PM_{2.5}, NO_x, traffic flow and other indicators.

Some provinces and cities in China have gradually carried out the pilot construction of roadside air quality monitoring stations, vehicle remote sensing monitoring stations, and road inspection stations. However, the monitoring station location selection combined with ‘important freight corridor and key roads’ mentioned in the above documents are basically based on human experience and judgment, and a scientific and reasonable quantitative layout method is urgently needed to support and guide the construction work.

3 Identification method of main highway freight corridors

Highway freight corridor refers to a cross-regional, long-distance, and high-intensity freight flow corridor composed of a highway network. It has the characteristics of intensive transportation resources and outstanding strategic status. There is a certain inherent imbalance in transportation, and some small amount of lines, sections, and nodes are always the focus and key of overall efficiency. Objectively, the phenomenon of ‘centralized traffic’ has emerged, which means that key facilities have assumed a high proportion or critical transportation. USA uses indicators such as the Annual Average Daily Traffic (AADT) volume of the highway, the European Union considers the annual traffic volume to account for 1% of the total EU traffic volume, and China uses the truck-converted AADT to identify the key lines.

China has organized a nationwide normalized highway traffic survey. By the end of 2018, 44,000 stations for

Table 1. Screening criteria for highway freight corridors and high truck intensity road sections.

Criteria I	Criteria II
①Heavy-duty truck weighted AADT ≥ 15000 PCU per day and ②Heavy-duty truck weighted AADT proportion of all car $\geq 50\%$	①Heavy-duty truck weighted traffic ≥ 5000 vehicles per day and ②Heavy-duty truck weighted traffic proportion of all car $\geq 30\%$

4 Layout method of monitoring stations for diesel freight trucks emission

For monitoring purposes, diesel truck emission monitoring and supervision facilities can be divided into two categories: ① master the trend of air quality changes along high truck intensity road sections -Roadside Air Quality Monitoring Stations; ② identify high emission (or excessive emission) diesel trucks - Motor Vehicle Remote Sensing Automatic Monitoring Station and Road Manual Inspection Station.

The United States, New Zealand and other countries have accumulated some experiences in the construction of near-road air quality monitoring networks and high-emission vehicle monitoring. USEPA Near-Road NO₂ Monitoring Technical Assistance Document stipulates that all cities with a population of more than 500,000 should set up a monitoring site. If the population exceeds

highway traffic survey have been established across the country. Highway traffic survey is to conduct regular or irregular surveys on the traffic conditions of national roads, provincial roads, county roads, rural roads and special roads. It can grasp the traffic flow characteristics, such as traffic volume, traffic flow distribution, traffic flow composition, vehicle speed.

We can use real-world highway traffic survey data to find ‘centralized traffic’ route sections. The formed ‘intermittent line’ basically outlines the most centralized traffic routes for regional freight, reflecting the basic pattern of highway freight corridors naturally formed by industrial structure, urban structure, population consumption, geography and infrastructure conditions. Identifying the main highway freight corridors in the region is helpful to grasp the main hotspots and driving routes of diesel trucks. Concentrating limited resources of monitoring stations on important highway freight corridors or high truck intensity sections will significantly increase the efficiency of regional diesel truck monitoring and supervision.

This study carried out a large number of statistical analysis and calculations on national highway traffic survey data. National Comprehensive Freight Corridor Planning of China puts forward the standard of ‘lines with the truck-converted AADT ≥ 15000 PCU/d’ (Converted cargo flow density ≥ 31200 kilotons/year) as the freight corridor. National research program for key issues in air pollution control of China sets the standard of ‘lines with heavy trucks weighted traffic ≥ 5000 vehicles per day and a proportion of all cars $\geq 30\%$ ’. Based on the distribution of truck traffic data, the screening criteria for regional highway freight corridors and urban high truck intensity road sections are presented in the following table 1.

2.5 million or the AADT exceeds 250,000 vehicles, an additional monitoring site is required. New Zealand's highway ambient air monitoring stations are mainly considered to be located within 100 meters of the monitored road, of which AADT should be greater than 20,000 vehicles per day or a known traffic jam section. The Ministry of Transport of China issued the National Highway and Waterway Transportation Environmental Monitoring Network Master Plan in 2015, and proposed to establish a number of transport-related air pollution monitoring stations within the scope of national transportation infrastructure with high traffic volume, high activity level and environmental sensitivity. The Ministry of Environmental Protection of China issued the Measurement Method and Specifications for Exhaust Pollutants from In-use Diesel Vehicles by Remote Sensing Method in 2017, which only stipulated that the monitoring station should be located in the long and uphill roads with good vision, missing detailed layout method. Overall, the Chinese vehicle emission monitoring layout method is

particularly prominent aspects of the short board. Based on the effective identification of the main highway freight corridors for regional diesel trucks, this study proposes a set of layout method of diesel truck emissions monitoring and supervision stations.

4.1 Roadside air quality monitoring station

In order to fully reflect the air quality characteristics of the highway network, multiple factors are considered in the layout of roadside air quality monitoring station, including highway network layout, highway administrative grades and technical grades, highway freight corridors, inter-city transportation routes, port access road, highway traffic survey station, location of large industrial and mining enterprises and logistics parks, and ambient air sensitive objects.

① At least one set of air quality monitoring stations should be installed on the highway freight corridors passing through the prefecture-level cities and ports every 50 km.

② A set of air quality monitoring stations should be installed every 50 km on the main inter-city transportation lines with AADT more than 30,000 vehicles.

③ A set of air quality monitoring stations should be installed in the typical tunnel with a length of more than 3 km and heavy-duty truck weighted AADT more than 15000PCU per day.

④ A set of air quality monitoring stations should be installed in the typical highway service area with heavy-duty truck weighted AADT more than 15000PCU per day.

4.2 Vehicle remote sensing monitoring station

To effectively monitor diesel trucks for excessive emissions, multiple factors are considered in the layout of vehicle remote sensing monitoring station, including highway network layout, highway freight corridors and high truck intensity road sections, highway overrun detection station, highway traffic survey station, highway toll station, location of large industrial and mining enterprises and logistics parks, and populated area.

① At least one set of remote sensing monitoring stations should be installed on the high truck intensity road sections passing through the main city and populated area every 50 km.

② A set of remote sensing monitoring stations should be installed on the high truck intensity road sections at the intersection of the provincial border.

③ A set of remote sensing monitoring stations should be installed on the high truck intensity road sections involving the import and export of the port area.

④ A set of remote sensing monitoring stations should be installed on the high truck intensity road sections at the entrance of large industrial and mining enterprises involved in bulk material transportation.

4.3 Road inspection station

Highway overrun detection stations are often located at the provincial border entrances of national or provincial highways, at the intersections of multiple national or provincial highways, and at major highway corridors of inter-provincial freight transportation, which can be used as diesel truck exhaust emissions detection site. In order to complement remote sensing monitoring sites and jointly serve emissions supervision, multiple factors are considered in the layout of road inspection station, including highway network layout, high truck intensity road sections, and highway overrun detection station.

① Based on the location of existing overrun detection stations, at least one road inspection station should be set up in each city's high truck intensity road section.

② Based on the location of existing overrun detection stations, at least one road inspection station should be set up on the high truck intensity road sections passing through the main city and populated area every 50 km.

③ Based on the location of existing overrun detection stations, at least one road inspection station should be set up on the high truck intensity road sections leading to large industrial and mining enterprises and logistics parks.

5 Layout plan of monitoring stations for in-use diesel freight trucks emission in Shanxi Province

Shanxi Province is an important coal resource province and energy base in China, which has prominent features of the coal-dominated industrial structure, energy structure, and transportation structure. By the end of 2018, the total mileage of highways in Shanxi Province has reached 143,000 km, among which 5604.8 km are expressways. Shanxi province's freight volume has exceeded 2.1 billion tons, of which highway freight accounts for 60%. Shanxi province has more than 400,000 diesel trucks, which is the main force for bulk cargo transportation. Meanwhile, Shanxi Province is a must-go place for western coal transportation to east, and there is a large traffic flow of transit trucks, with about 180,000 field trucks passing on highways per day. In 2019, the Shanxi Province Implementation Plan for Deepening Pollution Control of Diesel Freight Trucks and Bulk Material Carriers was issued, which clearly required the construction of monitoring stations on the main highway freight corridors.

Therefore, this study is based on 2018 data of 5,945 highway traffic survey stations in Shanxi Province.

Using the proposed methods, high truck intensity sections are identified, and the 'intermittent line' are connected according to the existing lines and plan. This study identified 14 highway freight corridors across the province (Figure 1a), and 27 high truck intensity sections in 11 cities (Figure 1b, 1c).

In accordance with the guiding ideology of 'comprehensive coverage, focused emphasis, reasonable layout, and appropriate scale', and above-mentioned layout principles, spatial data analysis were conducted. After merger and optimization, a layout plan of

monitoring stations for in-use diesel freight trucks emission in Shanxi Province was formed, which screened out 44 roadside air quality monitoring stations, 24 vehicle

remote sensing monitoring stations, and 15 road inspection stations (Figure 2).

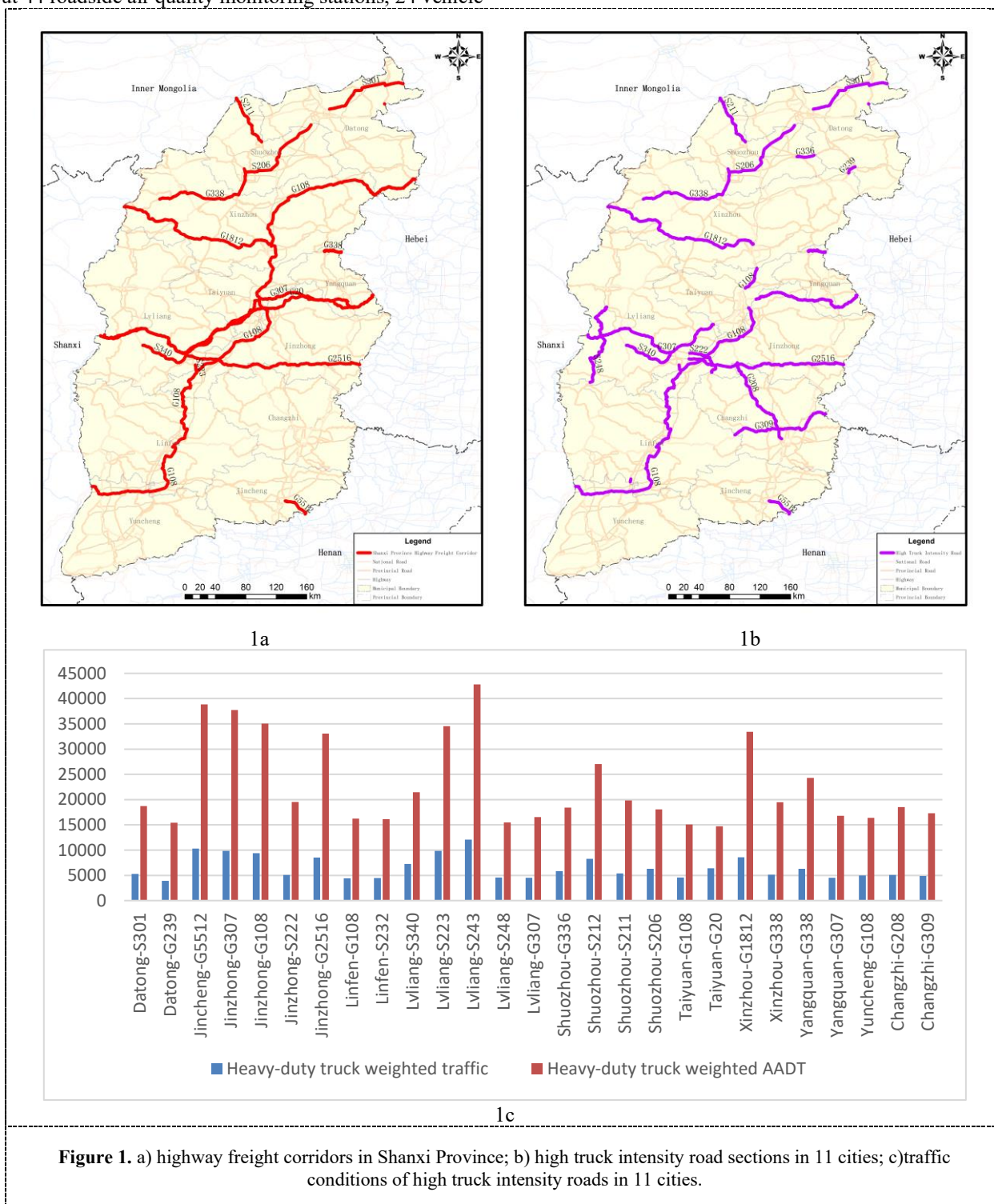


Figure 1. a) highway freight corridors in Shanxi Province; b) high truck intensity road sections in 11 cities; c) traffic conditions of high truck intensity roads in 11 cities.

6 Conclusion

This study has initially established a set of identification method of highway freight corridors and the layout method of diesel truck emissions monitoring and supervision stations based on highway traffic survey data, which can provide a technical reference for diesel truck

pollution control. In the future, it is possible to further optimize and adjust the layout technical method by considering the constraints of human and financial investment and supervision coverage requirements, and combining the related coupling analysis of diesel truck emissions monitoring data and highway traffic survey data. Meanwhile, in view of the strong mobility of diesel trucks, the administration departments shall dynamically adjust the spatial layout and configuration of monitoring and

supervision facilities according to the latest changes in the highway traffic flow.

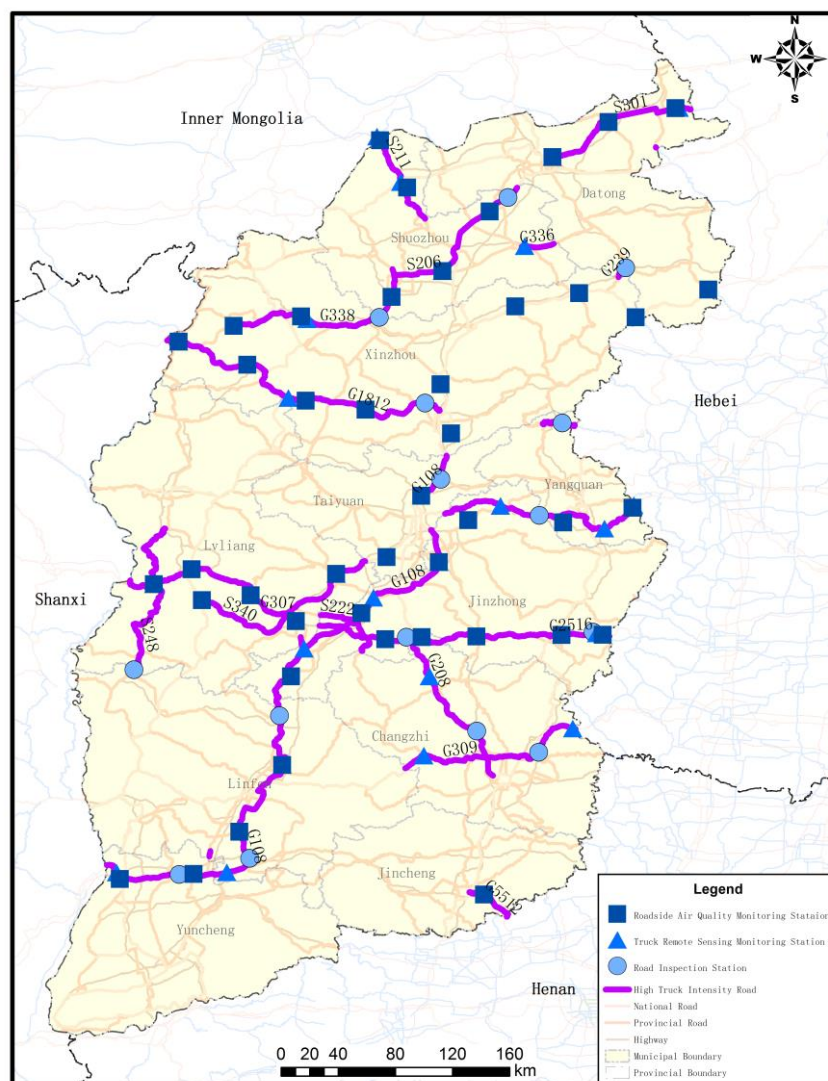


Figure 2. The layout plan of monitoring stations for in-use diesel freight trucks emission in Shanxi Province.

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