On the ambiguity of the impact of restricting the entry of heavy vehicles on the environmental situation in the metropolis

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Abstract. The calculation of indicators of heavy truck pollutant emissions for the implementation of the plans to restrict movement of heavy vehicles in the city of Krasnoyarsk (with arrangement of transshipment terminals at the entrance to the city for further transshipment of the delivered goods on lightweight trucks) has been made. The results demonstrate that the fuel consumption for the cargo delivery immediately depends on the truck load carrying capacity. The dependence of fuel consumption on the vehicle carrying capacity is close to linear. The restriction to intercity entry of heavy vehicles may lead to an increase in emissions of hazardous substances from the trucks by 2-18 thousand tons per year. The authors draw a conclusion that more comprehensive analysis of the potential adverse effects of restricting heavy trucks to enter the city is required.

1. Introduction

Motor vehicles, especially trucks of low ecological classes, prove to be sources of negative effects on the environment and human health [1]. Many countries put an official ban on the entry of heavy vehicles in large cities. In Russia, a temporary restriction or termination of the traffic on highways can be imposed in accordance with the Federal Law of 08.11.2007 No. 257-FL “About highways and on-road activities in the Russian Federation and on amendments to certain legislative acts of the Russian Federation”: 1) during the reconstruction and repair of roads; 2) in the period of occurrence of adverse climatic conditions, in the case of reducing the carrying capacity of the structural elements of the road, its sections and in other cases in order to ensure road safety; 3) in the period of increased intensity of movement of vehicles on the eve of non-working holidays and weekends, during holidays and at weekends, including rush hours of roads; 3) to ensure the effectiveness of the traffic management; 4) in other cases stipulated by federal laws, and with respect to regional or inter-municipal roads, local significance within the boundaries of settlements, including with the aim of increasing their capacity, by the laws of the constituent entities of the Russian Federation.

There is an opinion that it is heavy trucks that significantly contribute to the road destruction and are the main source of harmful emissions into the atmosphere of cities, hampering traffic flows. Therefore, it is believed that restricting the entry of heavy vehicles into the city will benefit the ecology improvement of the city. Is this the case?
2. Problem statement

Let us consider this problem by the example of the city of Krasnoyarsk, the largest transport hub of the Eastern Siberia. The availability of the Trans-Siberian Railway, the freight route on the Yenisei River, a large airport, including national, republican and local roads has an unfavorable impact on the overall environmental situation in the Krasnoyarsk agglomeration. Truck emissions in Krasnoyarsk account for 50-70% of the total emissions from motor vehicles [2, 3] with more than 60% of the amount of economic damage to air pollution from components and vehicle emissions from nitrogen oxides [2]. In this regard, in Krasnoyarsk, as in other large Russian cities, it is planned to impose restrictions on the entry of heavy vehicles [4]. To implement such plans will require the creation of transshipment terminals [5], and then the cargo will be transported by vehicles of smaller capacity in order to minimize the amount of harmful emissions within the city.

According to some authors, the Russian experience in building logistics centers suggests that similar projects have good commercial, budgetary and regional efficiency, and additionally contribute to improvement of the local ecological situation (owing to reduction of large trucks entrance into cities), as a complementary effect of saving urban land (data from the Eurasian region). Transport Union, EATL) [6]. There is an opposite point of view [5, 7].

Due to the ambiguity of opinions, the decision to limit the entry of heavy vehicles requires a comprehensive analysis of the positive and negative effects, including the impact on air pollution in the city. Therefore, it is necessary to analyze two options for delivering cargo to the city center (a heavy truck that transports the entire volume of cargo in one ride, or use lower load-carrying trucks to deliver goods for several riders) and decide on the most optimal option in respect of the amount of harmful emissions in the city.

3. Method of solution

It is known that the amount of harmful emissions from exhaust gases of internal combustion engines is directly proportional to the amount of fuel consumed. Therefore, in the first approximation, the analysis will be carried out by the amount of fuel consumed. For this, we do not take into account such factors as the type of fuel (diesel/gasoline), the environmental class of the vehicle, the technical condition of the vehicle, the skill of the driver, the system of maintenance and repair, and other factors affecting the emissions of harmful substances by trucks [1, 8, 9]. The commercial traffic travel into the city by highways is as follows:
- from the North by the Yenisei highway (highway P-409);
- from the South from the town of Divnogorsk (highway R-257 "Yenisei");
- from the West - along the Moscow highway (highway R-255 “Baikal”);
- from the East - from the village Berezovka (highway R-255 "Baikal").

For each of the directions on the point of entry we will model a transshipment terminal, namely: Terminal 1 (near the village of Startsevo), Terminal 2 (near the Laletin creek), Terminal 3 (near the village of Berezovka), Terminal 4 (near the village Yemelyanovo) and let us set the routes for deliveries of goods (Figures 1-4).

To deliver 20 MT of cargo, the following heavy trucks are required: 1 truck of Scania 340, 2 trucks of Mercedes 2535, 4 trucks of Hyundai HD-78, 6 trucks of GAZ 33104 and 10 trucks of Mitsubishi Canter.

To calculate the fuel consumption for each traffic route, we choose five trucks varying in their load-carrying capacities: Scania 340 (20 tons), Mercedes 2535 (10 tons), Hyundai HD-78 (4.8 tons), GAZ 33104 (3.5 tons), Mitsubishi Canter (2 tons), respectively.

4. Results

The tables below present the outcomes of calculation of the cumulative fuel consumption for transportation of 20 MT of cargo for each route, respectively.
Figure 1. The traffic entrance route from the entry point of Yenisseisk highway (P-409) to the Central market place with total route length of 20.7 km.

Figure 2. The traffic entrance route from the entry point of the town of Divnogorsk highway (P-257) to the Central market place ‘Novaia Vzletka’ (23.7 km).

Figure 3. The traffic entrance route from the entry point of the highway (P-257 ‘Yenisei’, town of Beriozovka) to the Trade Mall ‘Planeta’ (14 km).
Figure 4. The traffic entrance route from the entry point Yemelyanova (P-255 ‘Baikal’) to the Trade Mall ‘Leroy Merlin’ (12.5 km).

Table 1. The results of the fuel consumption for the route ‘Terminal 1’ – Central market place (northern destination). Route length – 20.7 km.

| Vehicle      | Average operational fuel consumption, L/100 km | Cumulative fuel consumption on the route, L | Cumulative fuel consumption on the route for delivery of 20 MT of cargo |
|--------------|-----------------------------------------------|-------------------------------------------|---------------------------------------------------------------------|
| Scania 340   | 40.0                                         | 8.3                                       | 8.3                                                                 |
| Mercedes 2535| 27.0                                         | 5.6                                       | 11.2                                                                |
| Hyundai HD-78| 18.0                                         | 3.7                                       | 14.8                                                                |
| GAZ 33104    | 17.0                                         | 3.5                                       | 21.0                                                                |
| Mitsubishi Canter | 14.0                                      | 2.9                                       | 29.0                                                                |

Table 2. The results of the fuel consumption for the route ‘Terminal 2’ – Market place ‘Novaia Vzletka’ (southern destination). Route length – 23.7 km.

| Vehicle      | Average operational fuel consumption, L/100 km | Cumulative fuel consumption on the route, L | Cumulative fuel consumption on the route for delivery of 20 MT of cargo |
|--------------|-----------------------------------------------|-------------------------------------------|---------------------------------------------------------------------|
| Scania 340   | 40.0                                         | 9.5                                       | 9.5                                                                 |
| Mercedes 2535| 27.0                                         | 6.4                                       | 12.8                                                                |
| Hyundai HD-78| 18.0                                         | 4.3                                       | 17.2                                                                |
| GAZ 33104    | 17.0                                         | 4.0                                       | 24.0                                                                |
| Mitsubishi Canter | 14.0                                      | 3.3                                       | 33.0                                                                |

Table 3. The results of the fuel consumption for the route ‘Terminal 3’-Trade Mall ‘Planeta’ (eastern destination). Route length – 14 km.

| Vehicle      | Average operational fuel consumption, L/100 km | Cumulative fuel consumption on the route, L | Cumulative fuel consumption on the route for delivery of 20 MT of cargo |
|--------------|-----------------------------------------------|-------------------------------------------|---------------------------------------------------------------------|
| Scania 340   | 40.0                                         | 5.6                                       | 5.6                                                                 |
| Mercedes 2535| 27.0                                         | 3.8                                       | 7.6                                                                 |
| Hyundai HD-78| 18.0                                         | 2.5                                       | 10.0                                                                |
| GAZ 33104    | 17.0                                         | 2.4                                       | 14.4                                                                |
| Mitsubishi Canter | 14.0                                      | 1.9                                       | 19.0                                                                |
Table 4. The results of the fuel consumption for the route ‘Terminal 4’ – Trade Mall ‘Leroy Merlin’ (western destination). Route length – 12.5 km.

| Vehicle          | Average operational fuel consumption, L/100 km | Cumulative fuel consumption on the route, L | Cumulative fuel consumption on the route for delivery of 20 MT of cargo |
|------------------|-----------------------------------------------|---------------------------------------------|------------------------------------------------------------------|
| Scania 340       | 40.0                                          | 5.0                                         | 5.0                                                              |
| Mercedes 2535    | 27.0                                          | 3.4                                         | 6.8                                                              |
| Hyundai HD-78    | 18.0                                          | 2.3                                         | 9.2                                                              |
| GAZ 33104        | 17.0                                          | 2.1                                         | 12.6                                                             |
| Mitsubishi Canter| 14.0                                          | 1.7                                         | 17.0                                                             |

According to the results of calculations (Figure 9) during the carriage of goods by the trucks of different carrying capacities, the amount of fuel consumed increases with the decreasing of vehicle carrying capacity, which is consistent with the literature data [8].

![Figure 5](image_url)  
Figure 5. The dependence of the cumulative fuel consumption of the vehicle carrying capacity and the length of the route.

Thus, when transporting 20 tons of cargo by vehicles with a carrying capacity of 10 tons, 4.8 tons, 3.5 tons and 2 tons, the fuel consumption (including emissions of pollutants) increases 1.4 times, 1.9 times, 2.5 times, 3.5 times, respectively, compared to the transportation of 20 MT- of cargo by a heavy truck.

Based on the data of Rosprirodnadzor [10] on the amount of emissions of hazardous substances from vehicles in the city of Krasnoyarsk, there is 73.1 thousand tons (in 2017) and the share of emissions from heavy trucks is 10% [3, 11]. We can predict the increase in the amount of emissions of harmful substances by trucks during transition to a logistics scheme for the transport of goods with restricted entry of heavy vehicles (Table 5).

Table 5. The forecast of increase in emissions of trucks with harmful pollutants in Krasnoyarsk in case of the ban of movement of heavy vehicles

| Load carrying capacity, MT | Order of emission gain depending of the load carrying capacity | Polluting emission in Krasnoyarsk, thousand MT/yr |
|----------------------------|---------------------------------------------------------------|-----------------------------------------------|
| 20.0                       | 1                                                             | 7.3                                           |
| 10.0                       | 1.4                                                           | 9.9                                           |
| 4.8                        | 1.9                                                           | 13.9                                          |
| 3.5                        | 2.5                                                           | 18.3                                          |
| 2.0                        | 3.5                                                           | 25.6                                          |
5. Conclusion
Based on the results of the first stage of the analysis, a conclusion can be made that the transportation of cargo by heavy trucks will ensure minimum cumulative fuel consumption, and, consequently, the minimum amount of emissions of hazardous substances with exhaust gases.

The final answer to the question about the feasibility (inexpediency) of restricting inter-city movement of heavy vehicles can be obtained based on the results of subsequent follow-up investigation. The purpose is to determine the outcome of heavy trucks by the speed of traffic movement in the city and the pattern of the concentration of harmful motor vehicle emissions in the surface air, patterns of traffic flow, meteorological conditions and other factors of the urban environment.

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