Methodology and examples for assessing the environmental performance of certain road traffic management measures

S V Shelmakov¹, T U Grigoreva¹

¹ Moscow automobile and road state technical university (MADI), 64, Leningradsky Prosp., Moscow, 125319, Russia

E-mail: shelwood@yandex.ru

Abstract. The article describes the methodology for assessing the impact of road traffic management (RTM) measures on the environment and public health. As an approbation of the methodology, such measures as ban on the movement of heavy trucks, ban on the movement of cars worse than the third ecological class and organizing the movement of non-motorized transport (NMT) are considered. Assessment of these measures impact on the environment was to provide an assessment of the pollutant emissions by the transport flow, the maximum and annual average ground-level concentrations of pollutants at the adjoining territory, the traffic flow noise characteristics (TFNC) and the equivalent sound levels at the adjoining territory. These estimates formed the basis for calculating public health risk indicators. Studies have shown that the greatest efficiency can be provided by measures to organize the movement of NMT and ban on the low environmental classes’ vehicles movement. It is also shown, that in addition to the traffic flows characteristics, specific features of the territory under consideration also have a significant impact on the results.

1. Introduction

According to [1], documentation on road traffic management (RTM) should be developed taking into account environmental safety and reducing the vehicles negative impact on the environment.

RTM measures are quite diverse and require a specific approach to their formalization in order to assess the potential environmental impact of their implementation. Many small activities, such as installing pedestrian traffic lights or artificial bumps, are a priori insignificant in environmental terms. Decisions on their implementation made mainly based on their effectiveness assessment in ensuring the safety of road users. But such measures as, for example, the organization of calm traffic zones, zones with a ban on entry of cars low environmental classes, or the creation of a citywide bicycle infrastructure, undoubtedly require justification of environmental efficiency.

It seems that decision-making on the implementation of most local RTM measures should be based on examples of best engineering practice: the measures that have proven effective in terms of improving road safety and/or in terms of improving the environmental situation in domestic and foreign practice can be implementing without any additional justification. On the contrary, deviation from the best engineering solutions should be justified, and only in some extraordinary cases. Examples of best engineering practice should be applied in the form of albums of typical solutions for organization of road traffic.

Decisions on the implementation of more complex RTM measures (not included in the albums of standard solutions) should be made using the methodology described below.
2. Object of research
This article considers a kilometer section of a 4-lane city street with an estimated capacity (in one direction) of 3000 vph, the actual traffic intensity during peak hours is 2200 vph (i.e., the traffic situation can be described as pre-traffic), the average flow velocity is 20 km/h, and the flow density is 65 v/km. Traffic composition: passenger cars – 85%, trucks – 10%, road trains – 1%, buses – 4%.

As examples, we considered four measures for RTM:
1. Removing congestion (this option is the basic one);
2. Removing congestion and narrowing the roadway to 2 lanes (for example, with the organization of non-motorized transport (NMT) – bicycles, scooters, segways, etc. – along the free lanes);
3. Removing congestion and ban on movement on this street section of the cargo vehicles with a gross weight more than 3.5 tons;
4. Removing congestion and ban on movement on this street section of the vehicles worse than the third ecological class.

The forecast scenario for a first (base) measures: the estimated street capacity will not change and will be 3000 vph, the projected traffic during peak hours going to grow up to 2800 vph, the average flow velocity is 60 km/h, the flow density will increase slightly and will be 25 v/km. The flow composition will not change: cars – 85%, trucks – 10%, road trains – 1%, buses – 4%.

The forecast scenario for a second measures: the estimated street capacity reduced to 1500 vph (organization for two-lane bike paths in one direction a capacity of about 2600 bph, so the total street capacity (in passenger traffic) in comparison with the first variant) will increase from approximately (when the passenger car interior filling ratio is equal to 1.6.) 4800 pph to 5000 pph, the projected traffic during peak hours will be 1400 vph, the average flow velocity is 60 km/h, the flow density will be 25 v/km. The composition of the flow will not change: cars – 85%, trucks – 10%, road trains – 1%, buses – 4%.

The forecast scenario for a third measures: the estimated street capacity will not change and will be 3000 vph, the forecast traffic intensity during peak hours will increase slightly (due to a denser flow without long trucks) and will be 2850 vph, the average flow velocity will not change and will be 60 km/h, the flow density will also increase slightly and will be 30 v/km. The flow composition will change: cars – 93%, trucks (gross weight less than 3.5 tns) – 3%, road trains – 0%, buses – 4%.

The forecast scenario for a fourth measures will be formulated as follows: the estimated street capacity will not change and will be 3000 vph, the forecast traffic intensity during peak hours will not change and will be 2800 vph, the average flow velocity will not change and will be 60 km/h, the flow density will not change and will be 25 v/km. The composition of the flow will also not change, but its structure will change according to environmental classes: only Euro-3 and higher cars with proportional distribution will remain.

For the examples of RTM measures under consideration, we will set the necessary characteristics of transport flows in a simplified version. The composition of traffic in all scenarios we assume the following:
- passenger vehicles – all “middle” class with a petrol engine with a uniform distribution on environmental classes (Euro 0,1 – 20%; Euro-2 – 20%; Euro-3 – 20%; Euro 4 – 20%; Euro 5 – 20%);
- cargo vehicles – small class (gross weight up to 3.5 t) – 80% (all petrol); large class (gross weight over 3.5 t) – 20% (all diesel) with a uniform distribution of environmental classes (Euro-0,1 – 20%; Euro-2 – 20%; Euro-3 – 20%; Euro-4 – 20%; Euro-5 – 20%);
- road trains – all diesel with a uniform distribution by environmental class (Euro-0,1 – 20%; Euro-2 – 20%; Euro-3 – 20%; Euro-4 – 20%; Euro-5 – 20%);
- buses – small class (gross weight up to 3.5 t) – 70% (all petrol); large class (gross weight over 3.5 t) – 30% (all diesel) with a uniform distribution of environmental classes (Euro-0,1 – 20%; Euro-2 – 20%; Euro-3 – 20%; Euro-4 – 20%; Euro-5 – 20%).
3. Description of the method

The methodology for assessing the environmental and public health impact of the RTM measures implementation is as follows:

- a base and one or more forecast scenarios for the implementation of RTM measures are formulated;
- based on the expert assumptions or transport modeling, the impact of the considered RTM measures on the traffic flows characteristics for each scenario is determined;
- based on the methodology for estimating pollutant emissions by motor transport, the maximum single (with an averaging period of 20...30 minutes) pollutant emissions on the studied street sections are determined for each scenario;
- based on the methodology of noise estimation, the traffic flow noise characteristic (TFNC) is determined for each scenario;
- based on the calculating methodology of pollutant dispersion in the atmosphere, the ground-level maximum single (i.e., characterizing the most unfavorable scattering conditions) concentrations are calculated at the selected points for each scenario;
- based on the characteristics of non-stationary traffic flow and meteorological parameters, long-period (average annual) pollutant concentrations are calculated at the selected points for each scenario;
- based on the methodology of sound propagation in the environment, maximum and equivalent sound levels are calculated (and, if more accurate estimates are needed, sound pressure levels) at selected points for each scenario;
- based on methods for assessing the public health risk from air pollution and noise factors, appropriate risk indicators are calculated for those population groups that are negatively affected by the traffic flows under consideration, for each scenario;
- based on cost-of-living and health methodologies, economic damage is calculated for each scenario;
- based on a comparison of the base scenario with the forecast(s), the economic effect of the considered measures implementation under the RTM is estimated;
- the information obtained is used when making a decision of the considered RTM measure implementation.

This is the most complete sequence of actions. In some cases, it is not necessary to reach economic estimates of the damage in absolute terms (in money), but rather enough to obtain relative estimates of the RTM measures effectiveness (as a percentage). It is sufficient to estimate changes in the levels of primary impact on the environment, i.e. calculate the change in pollutant emissions and TFNC forecast scenario relative to the base. In other words, there is no need to carry out the most labor-intensive and highly error-prone calculations of pollutant scattering and sound propagation, as well as all subsequent stages. The possibility of such a "truncation" of a calculations sequence is to the linear relationship of all estimated parameters with the magnitude of primary impacts, i.e. pollutant emissions and TFNC.

In this article, this methodology was used to assess the environmental performance of 4 road traffic management measures before the stage of calculating ground-level concentrations of pollutants and noise levels. The assessment of risk and environmental and economic damage for the examples under consideration will be discussed in the next article.

4. Results and Discussion

4.1. Determination of the maximum single pollutant emissions on a street section

The traffic characteristics for each scenario serve as input data for assessment methodologies of pollutant emissions from vehicles. The goal is to estimate the maximum single pollutant emissions (g/s) from vehicles on the studied street section.
The considered examples were calculated in the COPERT 5.3 program, which implements the EMEP/EEA methodology [2]. The results are shown in Fig. 1 ... 4.

From these Figures, it is clear that the best effectiveness for all pollutants is provided by the scenario with the 2 lane removal for the organization of NMT traffic: the reduction of pollutant emissions is proportional to the decrease in traffic intensity.

In second place by effectiveness is the ban on the old "dirty" cars movement. In this case, the effect is most pronounced for normed pollutants (CO, VOC, NOx) removed from exhaust gases by their purification systems, and less pronounced for pollutants, the emission of which is correlated with fuel consumption (CO2, SO2) or is caused not only by fuel combustion processes, but also by tire and brake wear (dispersed particles of various fractions).

Measures related to changes in traffic mode and traffic flow composition (classical RTM measures) are less effective and the effect is differentiated by various levels.

4.2. Determination of the traffic flow noise characteristics (TFNC)

TFNC calculations for these examples were conducted in accordance with [3]. The results are shown in Fig. 5. The range of possible values shown as error lines is due to possible combinations of factors other than the default values. A decrease in the $L_{Aeq}$ is possible if there is a low-noise road surface (crushed-mastic asphalt concrete), and an increase in the $L_{Aeq}$ – in the case of a noisy road surface (rough surface treatment) in combination with a 10% and longitudinal slope.
As follows from the examples considered, the change in the TFNC was most affected by a decrease in the velocity and intensity of traffic flow. The change in the flow composition was less effective, since the share of heavy-duty cargo vehicles in the considered examples is initially small. The change in the flow ecological structure did not change the TFNC, since the methodology [3] is not sensitive to this factor.

4.3. Evaluation of the ground-level maximum single pollutant concentrations

The calculation of the pollutant dispersion in the atmosphere was performed according to [4].

To calculate the pollutant dispersion, a number of additional input data must be set. Urban building was not accounted for, so as not to introduce additional uncertainty in the results. The meteorological parameters are chosen to characterize typical conditions in the Central European part of Russia and South-Western Siberia (shown in Figure 7 as error lines).

The highest concentration levels (in fractions of MPC) are observed for nitrogen dioxide. The concentration reaches its maximum values directly above the roadway, rapidly decreasing with distance (Fig. 6). The non-linear nature of this relationship demonstrates the importance of urban planning solutions for the mutual location of the highway and adjacent buildings. One of the most effective measures of protection against the road traffic negative impact is protection by distance.

Ban on movement for trucks can reduce the area of excessive air pollution at 19 m, the removal of one lane for introduction NMT traffic allows to reduce the area of excessive air pollution at 42 m, the ban on movement vehicles up to the ecological class Euro-3 allows to exclude the formation of excessive air pollution zone.

To assess the impact of pollutants on the territory adjacent to the road, average concentrations were calculated in the 500-meter zone adjacent to the roadway (Fig. 7).
Comparing the obtained results of ground-level concentrations with the results of emissions shown in Fig. 1 ... 4, it is necessary to note the relative hazard influence of a particular pollutant set by the MPCMR values. Thus, although nitrogen dioxide is released in smaller quantities, it creates a more dangerous concentration, since its MPC is much lower (harder) than that of the other pollutants shown in the figure. As for the effect on the pollutant concentration of the actual road traffic management measures under consideration, the analogy with the effect of these measures on the emissions of certain pollutants discussed above should be noted.

4.4. Estimation of the maximum and equivalent sound levels

For the examples under consideration, calculations of noise propagation in the adjacent territory are performed according to [5]. Urban buildings and the underlying surface were not taken into account, so as not to introduce additional uncertainty in the results. The results are shown in Figure 8.

This figure shows that the dependence of the equivalent noise level as a function of the distance from the road is non-linear. This indicator, as well as in the case of ground-level concentrations, can be effectively suppressed by increasing the distance from the road to the protected objects. Thus, proper planning of roads (streets) and adjacent buildings can significantly reduce the acoustic impact of traffic on the environment and public health.

Banning the movement of trucks will reduce the excess noise zone by only 2 m, removing one lane of the roadway for the NMT traffic organization will reduce the excess noise zone by 10 m, both by reducing the TFNC and by shifting the noise source position at 3.5 m (lane width) to the axis of the road.

Figure 6. Changes in the ground-level concentration of nitrogen dioxide depending on the distance from the road for the considered RTM measures

Figure 7. Average pollutant concentrations in the 500-meter zone adjacent to the roadway, for the examples considered

Figure 8. Change in the equivalent noise level depending on the distance from the road for the considered RTM measures

Figure 9. Change in the equivalent noise level depending on the distance from the road, when a noise shield was installed
To compare the effectiveness of the considered RTM measures on acoustic comfort in the territory adjacent to the street, calculations of the equivalent noise level were made, taking into account the installation of a 4 m high noise shield along the edge of the roadway. The results for the noisiest base scenario (velocity 60 km/h without congestion) are shown in Figure 9. This figure shows that the installation of a 4-meter noise shield allows to completely eliminate the zone of excess noise, both during the day and at night. This example shows the importance of applying engineering measures to protect against noise propagation, along with RTM measures.

5. Conclusion

Based on the analysis of domestic and foreign experience, the structure and content of the methodology for assessing the environmental and socio-economic effectiveness of road management measures are determined.

Studies have shown that the greatest effectiveness can be provided by measures to organize the NMT traffic and ban the traffic of low environmental classes vehicles. It is also shown that in addition to the characteristics of traffic flows, specific features of the territory under consideration also have a significant impact on the results.

References

[1] Federal Law No. 443-FZ of 29.12.2017 (as amended on 15.04.2019) "On the organization of road traffic in the Russian Federation and on amendments to certain legislative acts of the Russian Federation”.

[2] EMEP/EEA emission inventory guidelines 2009, 2013, 2016. Available at: http://www.eea.europa.eu (accessed 20.10.2020).

[3] SP 276.1325800.2016 Set of rules. The building and grounds. Design guidelines protection from the noise of the traffic.

[4] Methodology for calculating the dispersion of emissions of harmful (polluting) substances in the atmospheric air. (Order of the Ministry of natural resources of Russia dated 06.06.2017 No. 273).

[5] SP 51.13330.2011 Noise protection.