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Relationship Between Road Traffic Composition and Noise Emission: an Investigation Based on Hungarian National Public Road Traffic Data

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Abstract

Different vehicles contribute to the noise emission of the total road traffic in different ways and degrees. Therefore, emission calculation methods classify road vehicles based on their typical noise emission parameters. This article investigated the role of the four vehicle categories of CNOSSOS-EU method (light motor vehicles, medium heavy vehicles, heavy vehicles, and powered two-wheelers) in generating road traffic noise emissions. Based on traffic data available for national public roads in Hungary, the proportion of each vehicle category in the total road traffic was determined, providing the average distribution and other statistical parameters for each road category. The impact of changes in the traffic composition on noise emission was analysed based on the statistical parameters. The results show the dominance of light vehicles for all road categories (76–89% on average). The average proportion of heavy vehicles is also significant on controlled-access highways (motorways: 21%, expressways: 15%) and main roads (9%). The deviation from the average traffic composition can cause a noticeable difference in road traffic noise emission (up to nearly 3 dB). It was found that the impact of changing the proportion of heavy and light vehicles on noise emission is higher on roads inside built-up areas.

Keywords

road traffic noise emission, vehicle categories, traffic composition, CNOSSOS-EU method

1 Introduction

Environmental noise pollution is a growing challenge worldwide, causing health problems among the population exposed to long-term load. According to the 2020 European Environment Agency (EEA) report, more than 20% of the European population is affected by noise exposure exceeding levels harmful to health (EEA, 2020). Traffic noise, especially road traffic noise, is primarily responsible for causing negative effects. Based on the results of the 2017 strategic noise maps of the EU member states, more than 113 million people live in areas where road traffic noise exceeds the EU threshold of 55 dB established for the L_{den} day-evening-night noise index (EEA, 2020). A noise level exceeding the threshold of 50 dB for the night-time noise indicator (L_{night}) affects nearly 80 million people (EEA, 2020). Based on a detailed investigation of the health effects of noise exposure, the recommendation of the World Health Organization (WHO) indicates lower levels (53 dB and 45 dB, respectively) as the limit of health risk (WHO, 2018). Considering this, the number of people affected is even more significant. It can, therefore, be concluded that the efficient management of road traffic noise is a particularly important element of environmental noise protection. This requires adequate knowledge of the mechanism of road traffic noise emission.

Road traffic noise emission is significantly influenced by traffic characteristics, including volume, composition, and speed (Elkafoury et al., 2023; Umar et al., 2024). Based on studying fifty articles on artificial intelligence-based traffic noise prediction models, Umar et al. (2024) found that vehicle category is believed to be a major factor contributing to traffic noise. Therefore, the mathematical models for noise emission calculation classify road vehicles into different categories based on the parameters that characterise them from an acoustic point of view. Some calculation methods only consider the proportion of heavy vehicles [HV%] (e.g., Elkafoury et al., 2023; Ibili et al., 2022; Kumar et al., 2011), while other, more complex models distinguish between

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several vehicle categories (Cirianni and Leonardi, 2012; Wickramathilaka et al., 2023). The national noise calculation methods also handle this issue differently. The CRTN method, published in 1988 and applied in the UK, considers light vehicles and the percentage of heavy vehicles (HMSO, 1988). The NORD2000 method, developed by the Northern European states, has input parameters for light, medium, and heavy vehicles (Kragh, 2006). The Hungarian calculation method distinguishes three acoustic vehicle categories: 1. passenger cars and vans (<3.5 t); 2. single buses, light trucks (3.5 – 7 t) and powered two-wheelers; 3. articulated buses, heavy single unit trucks (>7 t) and long combination vehicles (Ministry of Environmental Protection and Water Management, 2007). The common noise calculation method of the EU (CNOSSOS-EU), which has replaced national methods in strategic noise mapping tasks, considers the following four categories: 1. light motor vehicles; 2. medium heavy vehicles; 3. heavy vehicles; 4. powered two-wheelers. There is a 5th "open category" for future needs (Commission Directive, 2015). The FHWA TNM method, applied in the United States, defines five categories: 1. automobiles; 2. medium trucks; 3. heavy trucks; 4. buses; 5. motorcycles (FHWA, 2019).

Examining each vehicle category's role, heavy vehicles' significant contribution to the total road traffic noise emission was shown using site investigation and model calculation (Kalansuriya et al., 2015; Wickramathilaka et al., 2023). Based on on-site measurements, Kalansuriya et al. (2015) found that the larger contribution of heavy vehicles to the noise levels is typical on higher-order roads, while the role of two-wheeled vehicles becomes significant on roads of local importance. Umar et al. (2024) found that the role of the categories is controversial, as each category was reported as a major factor contributing to traffic noise in different studies.

This article investigated the role of the four vehicle categories of the CNOSSOS-EU method in generating traffic noise emissions based on traffic data available for national public roads in Hungary. At first, the share of each vehicle category in the total road traffic was examined, determining the average proportion and other statistical parameters for each road category. Based on these parameters, the effect of changes in the traffic composition on noise emission was investigated. Different scenarios of the change in traffic composition were examined, determining the noise emission level for each.

2 Materials and methods

The investigation into the traffic composition of the national public roads was based on the cross-sectional traffic flow data provided by the National Road Data Bank (OKA) for 2020 (Magyar Közút, 2021). The examined elements of the national public road network are shown in Table 1. The study did not involve junction branches and service roads of motorways and expressways.

The vehicle classes in the OKA database were classified into CNOSSOS-EU vehicle categories, as shown in Table 2.

The OKA database provides the annual average daily traffic values (AADT, vehicles per day) for road sections of a given length and category for each vehicle type and the total motorised traffic. At first, each vehicle category's annual average daily traffic values were determined for a given road section, summing the AADT values of the

Table 1 Road categories examined in the study

Road category	Level	Description
motorways	controlled-access highway	2 + 2 travel lanes with emergency lane, central reservation, no at-grade intersections
expressways	controlled-access highway	mostly 2 + 2 travel lanes without an emergency lane, central reservation, and some at-grade intersections
primary main roads	main road	main road with national importance
secondary main roads	main road	main road with regional importance
link roads	side road	connects main roads
access roads	side road	connects a settlement with a main road
roads leading to a station	side road	connects a settlement with a station

Table 2 CNOSSOS-EU vehicle categories and OKA vehicle classes

CNOSSOS-EU		OKA
Category No.	Name	
1	light motor vehicles	passenger cars, vans
2	medium heavy vehicles	single buses, medium-heavy trucks
3	heavy vehicles	articulated buses, heavy trucks, trucks with trailers, semi-trailer trucks, special heavy trucks
4	powered two-wheelers	motorcycles, mopeds

corresponding vehicle classes for the CNOSSOS-EU vehicle categories. Then, the following parameters were calculated for each vehicle category per road category:

- average proportion weighted by section lengths in the total motorised traffic,
- minimum and maximum values of the length-weighted proportions,
- 2.5th and 97.5th percentiles of the length-weighted proportions,
- the standard deviation of the length-weighted proportions.

The effect of traffic composition on noise emission was analysed by defining different traffic scenarios and comparing the noise emission levels (A-weighted sound power levels) determined for them. The noise emission levels were counted using the CNOSSOS-EU traffic noise emission calculation method (Commission Directive, 2015). A road section with a gradient of 0% and a reference road surface (consisting of an average of dense asphalt concrete 0/11 and stone mastic asphalt 0/11, between 2 and 7 years old and in a representative maintenance condition) and an air temperature of 20 °C was assumed. The speeds for each vehicle category were recorded following the speed limits currently in force in Hungary for each road category (Ministry of Transport and Posts and Ministry of Interior, 1975).

The comparison base for each road category was the average traffic composition determined based on the abovementioned OKA database. The examined scenarios were identified according to the following considerations:

- there was no change in the total number of vehicles. Only the traffic composition was varied compared to the average distribution,
- the lower (2.5th) and upper (97.5th) percentiles were the limits for varying the proportions,
- the focus was on increasing the proportion of heavy vehicles and then medium-heavy vehicles, as their noise emission are the most significant (heavy vehicles were examined for all road categories, medium-heavy vehicles only for side roads, where their average proportion reaches 4%),
- for heavy vehicles on motorways and expressways (where their proportion is the most significant), a decreased proportion compared to the average composition was also examined,
- the powered two-wheelers were examined on access roads, where their average proportion (4%) and the upper percentile value (21%) are relatively high,
- the increase/decrease in the proportion of vehicle categories 2–4 was compensated by the decrease/increase in the proportion of vehicle category 1,
- for each road category except motorways and expressways, roads inside and outside built-up areas were examined as separate sub-categories due to the different speed limits (roads outside built-up areas: 90 km/h for vehicle categories 1 and 4, 70 km/h for vehicle categories 2 and 3; roads inside built-up areas: 50 km/h for all vehicle categories).

According to these principles, the scenarios for each road category were as follows:

- scenario "0" (base scenario): average traffic composition,
- scenario "V3+": increase in the proportion of vehicle category 3 up to the upper percentile value, decrease in the proportion of vehicle category 1 by the same amount, but not more than up to the lower percentile value (if the increase in vehicle category 3 would exceed this value, it must also be reduced accordingly),
- scenario "V3−": decrease in the proportion of vehicle category 3 up to the lower percentile value, increase in the proportion of vehicle category 1 by the same amount, but not more than up to the upper percentile value,
- scenario "V23+": in addition to changes in scenario "V3+", increase in the proportion of vehicle category 2 and decrease in the proportion of vehicle category 1, according to the rules above (if the lower percentile value of category 1 was reached in scenario V3+, there is no scenario V23+),
- scenario "V4+": increase in the proportion of vehicle category 4 and decrease in the proportion of vehicle category 1, according to the rules above.

Table 3 shows the defined traffic composition scenarios. The nomenclature of the scenario codes is the following: *abbreviation of road category* (e.g., "MW" for motorways)–*sign of inside or outside built-up area* ("I" or "O") if necessary_ *sign of the scenario* (e.g., "V3+" for increase in vehicle category 3).

3 Results

The results of the traffic composition analysis of Hungarian national public roads are shown in Figs. 1–6. Some preliminary results have already been communicated (Balogh and Parászka, 2024).

Table 3 Traffic composition scenarios

Road category	Scenario code	Vehicle category 1	2	3	4
		Proportion in the total motorised traffic [%]			
Motorways	MW_0	76	3	21	0
	MW_V3+	60	3	37	0
	MW_V3−	95	3	2	0
Expressways	EW_0	82	3	15	0
	EW_V3+	71	3	26	0
	EW_V3−	94	3	3	0
Primary main roads – outside built-up areas	PMR-O_0	87	3	9	1
	PMR-O_V3+	62	3	34	1
Primary main roads – inside built-up areas	PMR-I_0	87	3	9	1
	PMR-I_V3+	62	3	34	1
Secondary main roads – outside built-up areas	SMR-O_0	87	3	9	1
	SMR-O_V3+	72	3	24	1
Secondary main roads – inside built-up areas	SMR-I_0	87	3	9	1
	SMR-I_V3+	72	3	24	1
Link roads – outside built-up areas	LR-O_0	89	4	4	3
	LR-O_V3+	80	4	13	3
	LR-O_V23+	72	12	13	3
Link roads – inside built-up areas	LR-I_0	89	4	4	3
	LR-I_V3+	80	4	13	3
	LR-I_V23+	72	12	13	3
Access roads – outside built-up areas	AR-O_0	86	6	4	4
	AR-O_V3+	74	6	16	4
	AR-O_V23+	64	16	16	4
	AR-O_V4+	69	6	4	21
Access roads – outside built-up areas	AR-I_0	86	6	4	4
	AR-I_V3+	74	6	16	4
	AR-I_V23+	64	16	16	4
	AR-I_V4+	69	6	4	21
Roads leading to a station – outside built-up areas	SR-O_0	86	5	5	4
	SR-O_V3+	72	5	19	4
	SR-O_V23+	66	11	19	4
Roads leading to a station – outside built-up areas	SR-I_0	86	5	5	4
	SR-I_V3+	72	5	19	4
	SR-I_V23+	66	11	19	4

Fig. 1 shows the characteristic traffic composition for each road category, presenting the length-weighted average proportions of each vehicle category in the total motorised traffic. The results show the dominance of light vehicles for all road categories, with an average proportion of 76% (motorways) and 82% (expressways) and more than 85% for the other

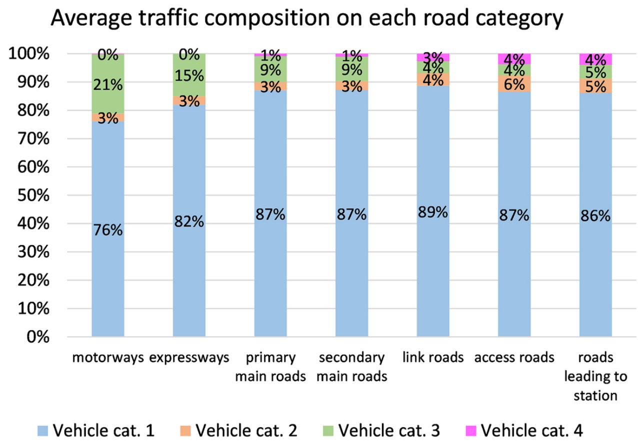

Fig. 1 Average traffic composition on each road category

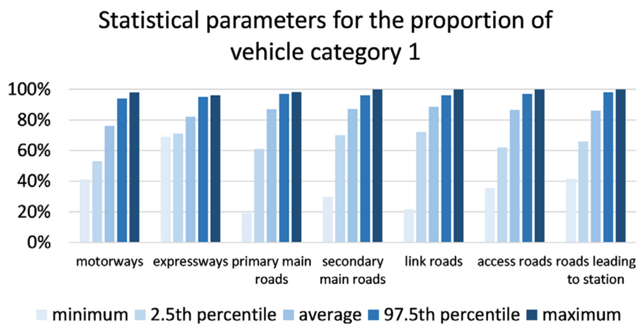

Fig. 2 Statistical parameters for the proportion of vehicle category 1

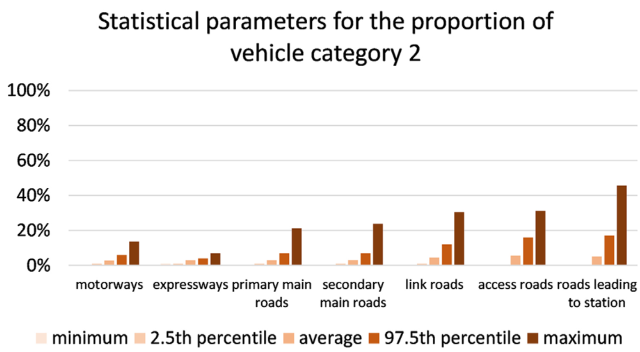

Fig. 3 Statistical parameters for the proportion of vehicle category 2

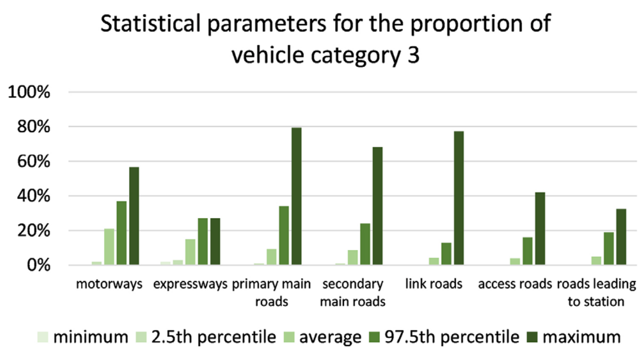

Fig. 4 Statistical parameters for the proportion of vehicle category 3

road categories. The average proportion of heavy vehicles is significant on controlled-access highways (motorways: 21%,

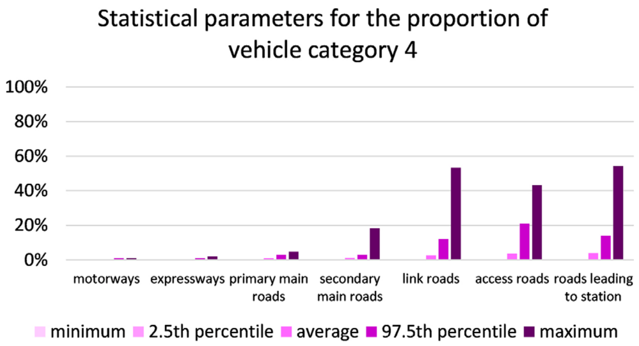

Fig. 5 Statistical parameters for the proportion of vehicle category 4

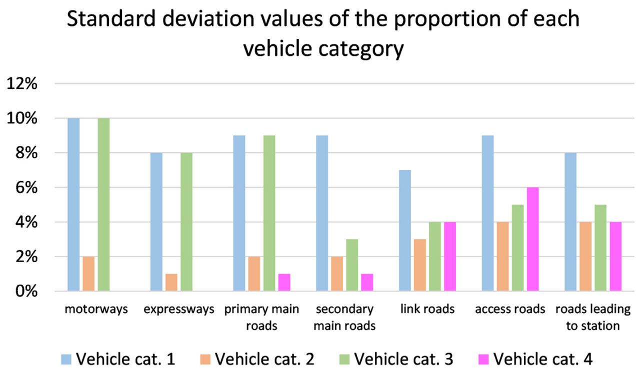

Fig. 6 Standard deviation values of the proportion of each vehicle category

expressways: 15%), while it does not reach 10% in other categories. The average proportion of medium-heavy vehicles is below 10% on every road category, slightly higher on side roads (4–6%) than on higher-ranking roads (3%). These values are significantly below the proportion of heavy vehicles on controlled-access highways and main roads, while on side roads they reach (link roads: 4–4%, roads leading to a station: 5–5%), or even exceed it (access roads: 6% vs. 4%).

The powered two-wheelers represent a 3–4% proportion on average on side roads, while their average participation in traffic on motorways, expressways, and main roads is negligible. The traffic composition on roads of the same level is typically similar: the average proportion of the same vehicle categories is the same on primary and secondary main roads, while they are quite close on different types of side roads. A significant difference can be seen only on controlled-access highways, in the average proportions of vehicle categories 1 and 3: the proportion of light vehicles is lower, while the proportion of heavy vehicles is higher on motorways than on expressways (vehicle category 1: 76% vs. 82%; vehicle category 3: 21% vs. 15%).

Figs. 2–5 presents the calculated statistical parameters (average proportions, extreme values, and percentiles) for vehicle categories 1–4 per road category. The 2.5th and 97.5th percentiles are more informative parameters than the minimum and maximum values of the proportions, due to the elimination of the distorting effect of possible outliers. Significant differences between the percentiles and the extreme values can be explained by such outliers. For example, the 20% difference between the 97.5th percentile (37%) and the maximum value (57%) determined for vehicle category 3 on motorways is caused by the proportion values of more than 50% detected on road sections with a total length of shorter than 10 km (which is less than 0.5% of the total length of the examined road sections in the given road category).

The standard deviation values of the length-weighted proportions for each vehicle category per road category are shown in Fig. 6. The highest values were detected for vehicle category 1 (7–10%), which is dominant in the traffic composition. Similar values were observed for vehicle category 3 on roads of a higher level (8–10%), while in the case of secondary main roads and side roads, where the average proportion of the category is lower, the standard deviation was smaller (3–5%). For vehicle categories 2 and 4, the standard deviation values are more significant on side roads (3–4% and 4–6%), where their average presence is also more considerable.

The results of the analysis of the traffic composition–noise emission relationship are presented in Table 4. For each examined scenario, Table 4 shows the difference in sound power level compared to the base scenario (average traffic composition) of the given road category.

For motorways, increasing the proportion of heavy vehicles to the upper percentile causes a 0.79 dB increase in noise emission level, while decreasing their proportion to the lower percentile results in a reduction of 1.18 dB. The results of the same scenarios for expressways are +0.59 dB and −0.76 dB, respectively. The higher reducing effect can be explained primarily by the shift in the proportions: the decrease of the proportion of vehicle category 3 to the lower percentile means that the heavy vehicle traffic nearly disappears. Further reason is the different distance of the upper and lower percentiles from the average value (there is a higher difference between the lower percentile and the average). The differences between the noise emissions for scenarios "V3+" and "V3−" are 1.97 dB for motorways, and 1.35 dB for expressways. It shows that traffic compositions, which occur rarely but with a real chance, can result in significant differences in noise emission.

For primary main roads, both inside and outside built-up areas, the increasing the proportion of heavy vehicles to the upper percentile causes more than 2 dB increase in noise

Table 4 Change in sound power level for each scenario

Road category	Scenario code	Difference in sound power level compared to the base scenario[dB]
Motorways	MW_V3+	+0.79
	MW_V3–	–1.18
Expressways	EW_V3+	+0.59
	EW_V3–	–0.76
Primary main roads – outside built-up areas	PMR-O_V3+	+2.19
Primary main roads – inside built-up areas	PMR-I_V3+	+2.90
Secondary main roads – outside built-up areas	SMR-O_3+	+1.44
Secondary main roads – inside built-up areas	SMR-I_3+	+1.96
Link roads – outside built-up areas	LR-O_V3+	+1.04
	LR-O_V23+	+1.40
Link roads – inside built-up areas	LR-I_V3+	+1.50
	LR-I_V23+	+2.21
Access roads - outside built-up areas	AR-O_V3+	+1.31
	AR-O_V23+	+1.73
	AR-O_V4+	–0.45
Access roads – inside built-up areas	AR-I_V3+	+1.81
	AR-I_V23+	+2.58
	AR-I_V4+	–0.27
Roads leading to a station – outside built-up areas	SR-O_V3+	+1.48
	SR-O_V23+	+1.72
Roads leading to a station – inside built-up areas	SR-I_V3+	+2.03
	SR-I_V23+	+2.48

emission level, which means a noticeable change. For primary and secondary main roads, the results show a higher effect of the change in the proportion of heavy vehicles on noise emission inside built-up areas than outside built-up areas. This is due to the speed dependence of the noise emission: as the speed limits are different for roads outside built-up areas (lower for vehicle category 3), while they are the same inside built-up areas, the impact of heavy vehicles on the noise emission is more pronounced inside built-up areas.

The same can be observed on side roads for both vehicle categories 2 and 3, inside and outside built-up areas. Comparing the effect of vehicle categories 2 and 3, it was shown that the increase in the proportion of heavy vehicles had a greater impact on noise emission. This can be partly explained by the fact that the increase in the proportion of category 2 was smaller for all road categories than in category 3 (e.g., 10% vs 12% for access roads). Further reason is the lower noise emission of the vehicles in category 2, which is considered in the CNOSSOS-EU method by calculation coefficients based on measurement results. Similarly, the noise-reducing effect of the increase in the proportion of powered two-wheelers (while the proportion of light vehicles decreases) is due to their acoustic parameters according to the CNOSSOS-EU method, which express their lower noise emission compared to the vehicles in category 1.

4 Conclusion

The presented study aimed at analysing the impact of traffic composition on road traffic noise emission. Based on traffic data available on national public roads in Hungary, the proportion of the four vehicle categories of the CNOSSOS-EU method in the total motorised traffic were examined for different road categories. Statistical parameters of the proportions were determined, which were considered in the development of scenarios for traffic composition. Finally, the noise emissions for each scenario were calculated and compared to each other.

The main findings of the analysis were as follows:

- a dominance of light vehicles was observed for all road categories, with a slightly lower average proportion on motorways and expressways than on the other road categories,
- the average proportion of heavy vehicles is more significant on roads of a higher level than on side roads,
- traffic composition different from the average can cause significant differences in road traffic noise emission,
- the change in the ratio of (medium) heavy and light vehicles has a greater impact on noise emission inside built-up areas than outside built-up areas, due to the different speed limits.

The differences in traffic composition can be caused by various reasons, e.g., regional differences or temporary situations affecting the traffic. The analysis of these causes, especially the regional differences, may be the subject of a further investigation.

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