THE ASSESSMENT OF POLLUTANTS EMISSIONS WITHIN SUSTAINABLE URBAN FREIGHT TRANSPORT DEVELOPMENT
The Case of Novi Sad

by

Marko S. VELIČKOVIĆ, Djurdjica M. STOJANOVIĆ *, and Valentina B. BASARIĆ

Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia

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Assessment of pollutant emissions is a prerequisite for planning and development of sustainable urban transport systems. Majority of extant studies on sustainable urban transport is focused on pollution caused by urban passenger transport, with marked paucity of literature on the impact of urban freight transport.
To partly bridge this gap, the paper objective is the impact assessment of selected regulative measures, i. e. fleet renewal on freight transport emissions. We used the case of Novi Sad to estimate the potential impact of selected restrictive measures on the external freight transport air pollution.
To the best of our knowledge, this is one of the first studies on impact of urban freight transport on the air pollution in the cities in the Balkan region.
Several research findings are of interest. Firstly, the analysis of particular gas emissions reveals expected overall positive effects of the fleet renewal in most of cases. Still, the total amount of same emissions hardly increase, so this particular measure is not enough to reach the ambitious EU strategy goals concerned with sustainable urban freight transport. Further, some negative impacts of restrictive measures on gas emissions were also recorded and discussed.
The observed complex impact of restrictive measures on urban freight air pollution indicates that urban freight transport planning and modeling requires a comprehensive database, clear goals and higher priority of environmental criterion in traffic planning. Our results and recommendations may be useful for scholars, urban transport planners, policy makers, and practitioners.

Key words: *urban freight transport, all-or-nothing assignment, air pollution, COPERT 4, engine technology restriction measures, urban transport planning*

Introduction

Serbia, as a developing country, is characterized by the increasing trend of urbanization and, correspondingly, urban traffic volume. Consequently, the problems related to more comprehensive vehicle urban activity are growing, with air pollution that originates from the movement of freight vehicles as one of the most important issues. The majority of vehicles on the road are powered by internal combustion (IC) engines and the IC engines for vehicles are generally fuelled with petrol or diesel. Passenger cars in 2009 were usually powered by petrol IC engines in Serbia, approximately 73% compared to 23.5% of diesel ones and 3.5% of liquefied petroleum gas (LPG) powered engines [1], while freight vehicles were mostly powered by die-

* Corresponding author; e-mail: djurdja@uns.ac.rs

sel IC engines. Although both engines have similar structures, they have significant differences in terms of operation, energy efficiency, and the amounts and types of emission they produce. It is well known that thermal processes in IC engines of freight vehicles produce higher exhaust emissions than passenger vehicles due to its size and workload.

The pollutant emissions are among the basic indicators used in development of sustainable urban freight transport policy and their assessment is a necessary precondition for the selection and implementation of regulative measures. However, while extant research was primarily focused on urban passenger transport emission and pollution, the interest on impact of urban freight transport on air pollution is still raising among the researchers and practitioners. There is paucity of research on urban freight transport air pollution and potential means and policy instruments capable of mitigating it in the South East European countries.

For these reasons, this paper aims to emphasize the impact of urban freight transport on air pollution, as well its significance in urban transport planning and control. We use the case of Novi Sad, the second largest city in Serbia, to evaluate the impact of selected restrictive measures on freight transport air pollution.

A literature review

As key business and investment centers, urban areas represent economic drivers. However, as urban population is increasing, many environmental problems are also concentrated in urban areas. Therefore, they play an important role in reaching the objectives of the EU Sustainable Development Strategy [2].

Freight transport makes a significant contribution both to the quality of life in cities and to the deterioration of traffic conditions and environment quality [3]. Urban freight is more polluting than long distance freight transport, due to the lower speed and high number of short trips and stops. Some estimations indicates that freight transport represents about 25% of CO_2 emissions stemming from transport activities in European cities, while freight transport generates between 20% and 60% (according the pollutants considered) of local transport-based pollution [4]. Greenhouse gas (GHG) emissions and noise pollution are also among the most severe environmental impacts of freight in cities. For all these reasons, urban freight planning plays an important role in the reduction of urban transport air pollution. The EU strategy puts forward benchmarks for achieving 60% GHG emission reduction in transport by 2050. These benchmarks include the ambitious goals of the zero greenhouse gas emissions and a substantial reduction of other harmful emissions from urban freight transport [4]. Local authorities have a crucial role in improving the urban environment and reaching these goals.

To make urban freight transport more sustainable, a range of measures is proposed [5] and partly explored in the literature [6, 7]. However, to select and implement the right mix of available regulative measures, it is necessary to make an assessment of their impact on pollutant emissions.

The fleet renewal is among the first regulative measures considered within the sustainable transport development. The contribution of urban trucks to total emissions varies with the type of truck (light *vs*. heavy), its engine type (gasoline *vs*. diesel), the conditions under which it operates (free flow *vs*. stop-start), the load carried, the mechanical condition of the engine, brakes, tyres, *etc*., and the total distance travelled [8].

In 2009, 183,391 light-duty and heavy-duty vehicles were registered in Serbia [1]. The Government of the Republic of Serbia identifies a range of problems related to sustainable transport development, including the freight transport, such as emission regulations do not comply with EU directives, absence of any incentives for reducing emissions, lack of rational management of transportation systems, vehicles that are not maintained and controlled in an appropriate manner and poor quality of motor fuels [9]. As the freight system in Serbia has a strong urban component, all identified problems could be also applied to urban freight transport. Furthermore, the urban traffic planners usually face the problem of a lack of comprehensive database on traffic flows [10] and, in particular, on freight transport. Consequently, the urban freight transport planning and control is often based on empirical evidence and intuition of local planners, rather than on comprehensive analysis and long-term planning. This is particularly the case for environmental impact of urban freight transport [11].

Methodology

With the area of 702.7 km^2 and a population over 300,000 inhabitants [12], Novi Sad represents the second largest city in Serbia and is thus one of the main economic drivers and freight attractors. In addition, the city is located near the European route E-75, which belongs to the key European motorway network. Although these characteristics have a positive impact on economic development, they negatively affect air quality, due to the extensive origin/destination and transit freight flows. Given this context, we have chosen to estimate pollutant emissions generated by freight vehicle movement in external flows (origin/destination and transit) in Novi Sad.

The spatial boundaries of research are the districts created for the purpose of this study, based on the established city zones in Novi Sad [13]. The existing urban zones are merged and aggregated in 10 city districts (see fig. 1), according to following criteria, similar as in [14]:

– the spatial distribution of the city contents, especially considering the industrial zone,
– the position of main city roads and transit traffic routes, and
– the characteristics of the existing traffic zones.

Once the city districts were defined, the focus was on the evaluation of freight transport emissions. As the actual emissions of air pollutants originating from freight vehicles are hard to measure directly, they have to be calculated by using available data on freight traffic volume estimation and projection.

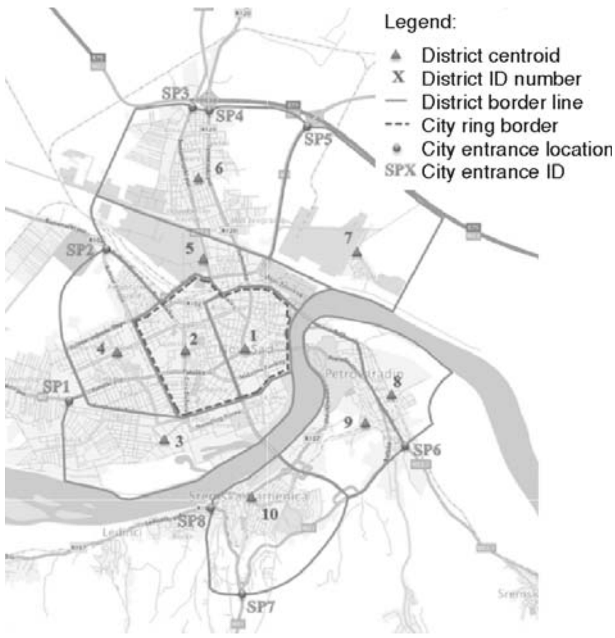

Figure 1. Districts and city entrance locations

Freight traffic volume estimation and projection

Recent pertinent studies used the data on number of vehicles and average annual mileage from TRENDS, TREMOVE, COPERT or MOBILE databases [15, 16]. However, as Serbia lacks an established and integrated monitoring systems on urban traffic data (traffic volume, mileage, *etc*.), in particular the ones related to freight transport, the data on traffic and freight transport volume in Novi Sad has to be gathered from other sources. The Public Enterprise "Urbanizam, Zavod za urbanizam", Novi Sad, conducted the "Novi Sad traffic study with dynamic traffic planning – NOSTRAM" in 2009 [17]. The traffic counting method and road user interviews at the outer cordon of Novi Sad were used to collect the traffic data, revealing that external freight traffic volume was 12,560 vehicles per day, corresponding to about 13% of total external daily traffic volume.

The factories, shopping centers, stores, and similar city contents are the main external freight flow attractors, the effectiveness of which is dependent on their operation. In this study, weekends (104 days) and national holidays (10 days) in 2009 were considered as non-working days and are used to project daily traffic volume to annual volume. Therefore, in the subsequent calculations, 251 days ware adopted as the number of workdays.

To assess the impact of selected urban transport policy measures on freight transport air pollution in Novi Sad, three periods are observed, whereby the data for the referent year 2009 is compared to the projected data for the years 2015 and 2020. The main input indicators are the external freight flow volume, while the main outputs are the annual freight vehicle emissions in observed years. The urban freight fleet structure is the parameter impacted by regulative measures and partly by natural fleet renewal.

Further, The Center for Roads of Vojvodina (CPV) from Novi Sad conducted a traffic study for a general project related to the ring road around the part of the city called Petrovaradin in 2010 [18]. Within this study, the freight traffic volume growth factors (according to the annual rates) were determined, based on the rank and the importance of a particular road. Table 1 shows these factors and rates for years 2015 and 2020, related to the referent year 2009. The adopted growth factors are also consistent with those ones used in other pertinent traffic studies [17, 19].

Table 1. Traffic volume growth factors and rates on road network – freight vehicles [18]

Year	Indicator	Road rank			
		M-21 Ruma	M-7 Futog	M-7 Zrenjanin	Secondary roads
2009-2015	Factor 2015	1.194	1.136	1.159	1.132
	Annual rate [%]	3.00	2.15	2.49	2.09
2009-2020	Factor 2020	1.767	1.477	1.681	1.416
	Annual rate [%]	5.31	3.61	4.83	3.21

In addition to the freight transport volume, the future emissions directly depend on vehicle type and technology it incorporates. Therefore, the fleet renewal is considered as the one of the most important emission reduction measures [20] and here it is related to the restrictive policy measures. Future fleet structure changes were projected based on the fleet structure trend in past two decades derived from the data gathered for Republic of Serbia [1].

The emissions originating from freight traffic in external traffic flows were calculated for the year 2009 and two scenarios were defined for future emission projections – Scenario 1, which assumes any controlled changes in vehicle technology ("do nothing" scenario – DoN) and Scenario 2, with entry restrictions into the city area for freight vehicles ("vehicle technology restrictions" – VTR). The restrictions are related to the vehicle type and engine technology, namely the technology lower than Euro I in year 2015 and lower than Euro II in year 2020. In the rest of the section, the relationship between vehicle type and emission calculation is described in detail.

Trip length

To estimate the routes used between each origin-destination (O-D) pair, we used "all-or-nothing" traffic assignment technique. The all-or-nothing technique assigns each O-D flow to the shortest travel distance connecting this O-D pair [21] and it represents the simplest route choice method with respect to the traffic scheme, with underlying consumptions, based on the following assumptions:

– no congestion effects are considered, and
– all drivers consider the same attributes for route choice, *e. g*. drivers perceive and weigh attributes for route choice in the same way.

The all-or-nothing approach yields a desired line, *i. e.* the route drivers would take if all choices were available to them and if congestion was not an impact factor in their decision-making process. This method is considered appropriate for freight vehicle assignment in external flows in Novi Sad, as a city act regulating the paths dedicated for such vehicles reduces the number of routes truck drivers can choose from. Also, the regulation of heavy duty vehicles entrance to inner city center does not completely eliminate these vehicles due to special allowances for their movement.

Nonetheless, in order to appreciate the limitations of this study, the following disadvantages of all-or-nothing assignment technique must be noted:

– this method is based on the assumption that all traffic will follow the shortest possible path,
– it cannot account for congestion effects, and
– it does not consider subjective judgments, rather assuming that all drivers consider the same attributes for route choice and weigh them in the same manner.

The movements between districts in city were not considered because the research focus was on the external freight flows.

The average trip length, calculated on the basis on empirical data, increases as vehicle load capacity is bigger, as follows:

– light duty vehicles: 7.21 km,
– medium duty vehicles: 7.46 km,
– heavy duty vehicles: 8.15 km, and
– very heavy duty vehicles: 8.85 km.

Emissions estimation methodology

EMEP/EEA emission inventory guidebook 2009 [22], last updated in May 2012, provides the guidance on estimating pollutant gas emissions arising from transport, as one of the main sources of air pollution in urban areas [23]. This guide describes the estimation method with three levels of increasing complexity. Thus, in order for this study to yield the best possible results, the calculation was performed based on Tier 3 approach, which is implemented in COPERT 4 (computer programme to estimate emissions from road traffic) model and is consistent with 2006 IPCC Guidelines [24] for the calculation of road transport emissions.

The COPERT methodology is used by over 20 European member states in their official reporting of national emission inventories for road transport [25]. It is primarily developed for emission estimations at a national level [26, 27]. As the incorporated model is structured to calculate urban, rural and highway emission factors separately, it is suitable for the estimation of urban and local air quality [15].

The emission factors (for the activity g/km) used in COPERT are specific for different vehicle types, fuel types, Euro classes, and engine capacity classes [28]. As this study focuses on freight transport, it relies on the 77 different freight vehicle types defined in COPERT software and the same number of emission factors for every pollutant emission from light duty vehicles (LDV) and heavy duty vehicles (HDV) activity. The calculation of total emissions is conducted by multiplying the appropriate emission factors for each vehicle type by its activity.

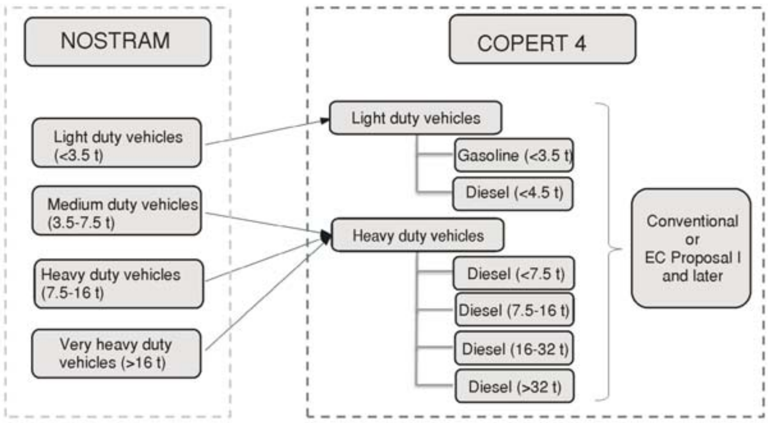

Figure 2. The relationship between NOSTRAM and COPERT vehicle categorization – Tiler 3

To apply the COPERT 4 methodology on the data obtained by NOSTRAM study, their vehicle categorizations have to be unified, as shown in fig. 2. As mentioned earlier, while COPERT includes 77 freight vehicle types covered by two categories, NOSTRAM study identifies four freight vehicle categories:

– light duty vehicles (<3.5 t),
– medium duty vehicles (3.5-7.5 t),
– heavy duty vehicles (7.5-16 t), and
– very heavy duty vehicles (>16 t).

For the purpose of transferring data from NOSTRAM to COPERT form, we calculated trip rates per vehicle type based on top-down approach, by using the structure of registered vehicles in Serbia in 2009 [1]. The number of trips per each vehicle category (related to the COPERT categorization) is then calculated before being used for emission calculations. Finally, by using the classified vehicle activity data and COPERT 4 emission factors, we estimated freight vehicle emissions in external traffic flows.

Total emission consists of two types of vehicle emissions based on engine working regime, namely hot and cold emissions, whereby the former are produced after the engine has reached its working temperature, and the latter arise during the warm up phase. Cold start emission is significant in urban areas for short or very short trips (less than 3 miles or ~5 km) [29]. Both types of emissions are included into the analysis.

The COPERT 4 emission factors are directly dependent of vehicle type and speed. Moreover, the software assumes that hot emission factors are dependent only on the average speed [30]. The uncertainties related to the average vehicle speed, inherent in the COPERT 4 methodology, can cause errors of up to 30% in the emission estimates [31]. As most observations of average urban speed (about 85%) range between 10 and 40 km/h, and 20 km/h is a suggested urban speed for emission estimation (ibid.), it is adopted as valid in this study.

Results

Vehicle activity

The spatial distribution of external freight traffic volume in Novi Sad in 2009 is shown in fig. 3, which depicts the origin, destination and transit freight traffic volume. It can be observed that the majority of external freight traffic volume – both transit and O-D trips – uses north and east city entrance roads. In addition, significant number of freight vehicles commences/terminates their trip in central business district, creating numerous negative effects on city environment.

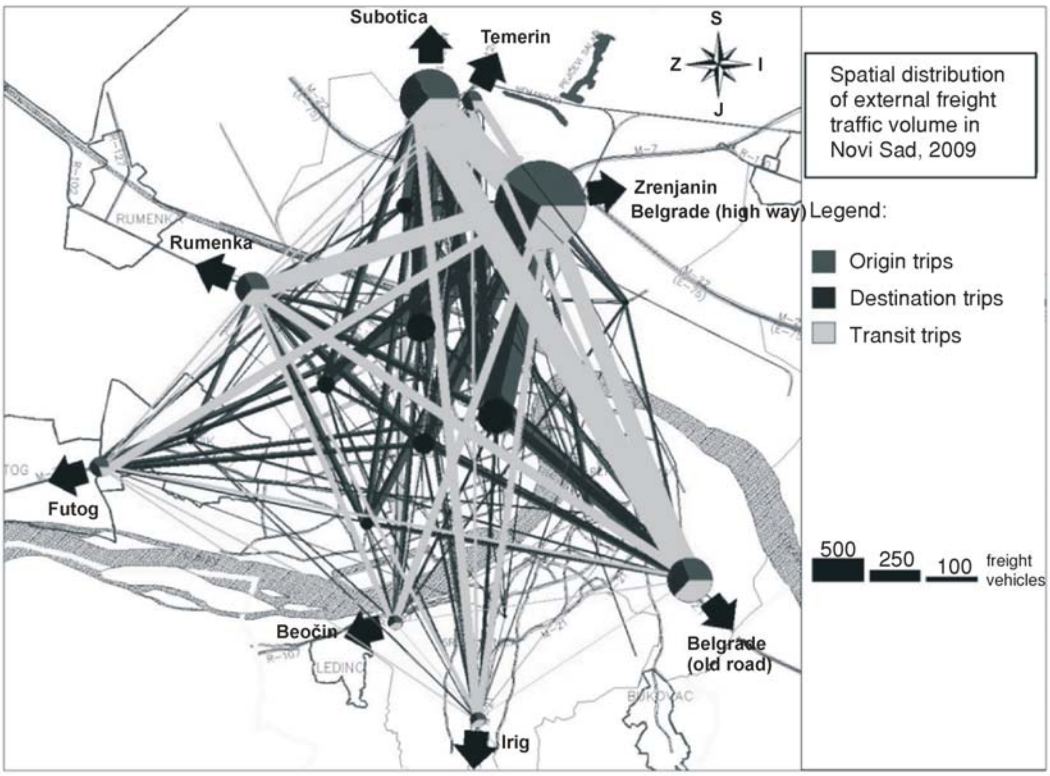

Figure 3. Spatial distribution of external freight traffic volume in 2009 (created by authors, according to [17])

Based on the daily external freight traffic volume and with respect to the number of workdays in Serbia, we have projected the external freight traffic volume for year 2009 (the base year for future traffic projections). Using the above traffic growth factors (given in tab. 1) for the base year traffic volume, we projected traffic volume for 2015 and 2020, as shown in tab. 3. Three main groups of vehicles will be used as appropriate for further analysis – gasoline and diesel light duty vehicles and heavy duty vehicles.

Table 3. Annual number of vehicles in 2009 and projections for 2015 and 2020

Vehicle groups	Fuel type	Year		
		2009 (base)[veh./year]	2015 [veh./year]	2020 [veh./year]
Light duty vehicles (LDV)	Gasoline	574030	657295	935145
	Diesel	1319514	1544356	2155417
Heavy duty vehicles (HDV)	Diesel	1199780	1399296	1968288
	Total	3093324	3600948	5058850

External freight transport emission estimation and projection

According to the methodology described in the previous section, the annual external freight transport emissions are calculated for the base year 2009 and projected for years 2015 and 2020. The summary results presented in tab. 4 pertain to different trip types.

Moreover, the projected freight traffic activity emissions are estimated for two different scenarios. The first scenario (Scenario DoN) assumes an estimation of natural change in future fleet structure, according to the trend of registered vehicles and new engine technologies data series and annual fleet assignments in past two decades [1, p. 97.]. The second scenario (Scenario VTR) includes the introduction of specific regulatory measures by the city authorities in Novi Sad, namely restrictions on external freight traffic flows with respect to engine technology limits. More precisely, in our model, we incorporated the implementation of regulatory measures by city authorities concerning entry restrictions into the city area for freight vehicles with technology lower than Euro I and Euro II, in 2015 and 2020, respectively. After we eliminated the conventional and Euro I vehicles in forecasted periods, we applied a vehicles assignment among the rest of the motor types, which is corresponding to [1, p. 97.]. Actually, it was assumed that the Euro I class in 2015 gains approximately the percentage of restricted conventional vehicles in 2009, while the Euro II class in 2020 incorporates the percentage of restricted Euro I vehicles in 2015. Further, new vehicle classes (Euro V and Euro VI for LDV, and Euro VI for HDV) are introduced in 2015 and 2020, respectively.

Figure 4 presents the share of emissions according to the fuel use and major vehicle type. Additionally, the first two bars on the same chart show the participation of individual vehicle categories in the total number of vehicles (NV) and the estimated fuel consumption per vehicle type (FC), respectively.

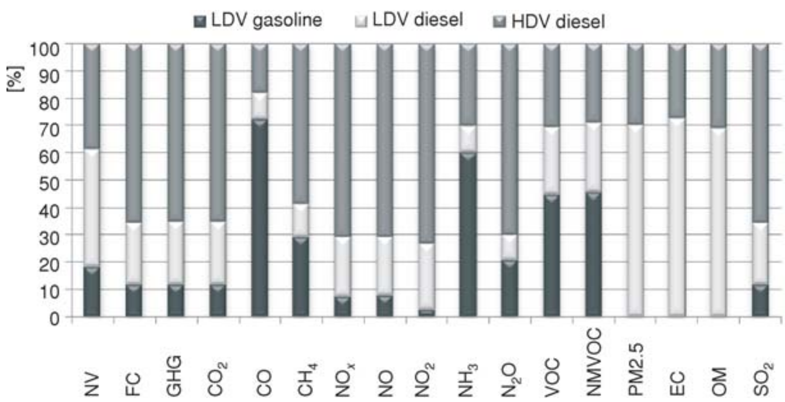

Figure 4. The participation of vehicles and fuel consumption compared to emission distribution by fuel type and main vehicle category in 2009

Table 4. Current and projected external freight transport emission by trip type

Scenario 1 – "Do nothing – DoN"												
Emision [t/year]	2009				2015				2020			
	Origin	Destin.	Transit	Σ	Original	Destin.	Transit	Σ	Origin	Destin.	Transit	Σ
CO_2	3642.75	3364.45	6167.34	13174.54	4184.08	3861.81	7078.17	15124.06	5887.08	5371.26	9883	21141.34
CO	55.45	42.25	46.84	144.54	58.5	46.07	51.09	155.66	85.11	63.52	70.25	218.88
CH_4	0.44	0.41	0.69	1.54	0.48	0.44	0.75	1.67	0.65	0.6	1.01	2.26
NO_X	36.42	28.71	58	123.13	38.39	31.42	64.05	133.86	55.25	42.19	87.17	184.61
NO	32.32	25.47	51.3	109.09	33.95	27.76	56.49	118.2	48.53	37.18	76.74	162.45
NO_2	4.1	3.24	6.71	14.05	4.44	3.65	7.56	15.65	6.72	5.01	10.42	22.15
NH_3	0.03	0.03	0.04	0.1	0.04	0.04	0.04	0.12	0.06	0.05	0.06	0.17
N_2O	0.06	0.06	0.1	0.22	0.07	0.06	0.11	0.24	0.09	0.09	0.15	0.33
VOC	17.41	6.23	8.9	32.54	16.42	6.56	9.23	32.21	27.74	8.77	12.21	48.72
NMVOC	16.96	5.82	8.21	30.99	15.94	6.11	8.49	30.54	27.09	8.17	11.2	46.46
$PM_{2.5}$	7.54	1.28	2.34	11.16	5.53	1.32	2.42	9.27	12	1.7	3.13	16.83
EC	4.77	0.74	1.34	6.85	3.73	0.79	1.43	5.95	8.13	1.03	1.89	11.05
OM	2.38	0.44	0.8	3.62	1.55	0.44	0.78	2.77	3.34	0.54	0.98	4.86
SO_2	0.09	0.09	0.16	0.34	0.11	0.1	0.18	0.39	0.15	0.14	0.25	0.54
Scenario 2 – "Vehicle technology restrictions – VTR"												
Emision [t/year]	2009				2015				2020			
	Origin	Destin.	Transit	Σ	Original	Destin.	Transit	Σ	Origin	Destin.	Transit	Σ
CO_2	3642.75	3364.45	6167.34	13174.54	4204.15	3856.43	6679.9	14740.48	5697.6	5191.33	9336.44	20225.37
CO	55.45	42.25	46.84	144.54	36.33	22.9	27.75	86.98	36.88	19.07	25.56	81.51
CH_4	0.44	0.41	0.69	1.54	0.22	0.2	0.42	0.84	0.18	0.17	0.33	0.68
NO_x	36.42	28.71	58	123.13	27.68	18.95	44.68	91.31	40.35	27.54	61	128.89
NO	32.32	25.47	51.3	109.09	24.07	16.37	38.79	79.23	33.91	23.36	52.66	109.93
NO_2	4.1	3.24	6.71	14.05	3.6	2.58	5.89	12.07	6.44	4.18	8.33	18.95
NH_3	0.03	0.03	0.04	0.1	0.13	0.12	0.12	0.37	0.27	0.25	0.24	0.76
N_2O	0.06	0.06	0.1	0.22	0.08	0.08	0.13	0.29	0.11	0.1	0.16	0.37
VOC	17.41	6.23	8.9	32.54	19.04	1.75	3.31	24.1	26.07	1.54	2.76	30.37
NMVOC	16.96	5.82	8.21	30.99	18.83	1.55	2.88	23.26	25.88	1.38	2.44	29.7
$PM_{2.5}$	7.54	1.28	2.34	11.16	7.84	0.58	1.21	9.63	10.91	0.69	1.16	12.76
EC	4.77	0.74	1.34	6.85	5.95	0.4	0.81	7.16	9.04	0.52	0.82	10.38
OM	2.38	0.44	0.8	3.62	1.7	0.12	0.28	2.1	1.64	0.14	0.25	2.03
SO_2	0.09	0.09	0.16	0.34	0.11	0.1	0.17	0.38	0.14	0.13	0.24	0.51

GHG are calculated as the equivalent carbon dioxide emission (CO_2e) which represents the sum of three main greenhouse gas (CO_2, CH_4, and N_2O) emissions, according to the Kyoto protocol [32]. Despite almost 60% participation of light duty vehicles in external freight flow volume, it is estimated that around 65% of fuel is consumed by heavy duty vehicles. The major sources of greenhouse gas (CO_2, CH_4, and N_2O) emissions are also HDV, accounting for an excess of 65%. Also, HDV emit the highest part of $PM_{2.5}$, EC, and OM. However, light duty vehicles are the major sources of CO, NH_3, and NMVOC, especially the gasoline powered LDV.

Discussion

Majority of studies on environmental impact of urban transport have been focused on passenger transport in the last decade, while the freight transport has received considerably less attention than it deserves, until recently. It is particularly applicable to developing countries, where the first reports have just started to herald the importance of urban freight transport impact on environment.

Until now, there has been a significant lack of research regarding to the environmental impact of urban freight transport in Serbia and other countries in Balkan region, with rare exceptions (*e. g.* see [11, 14]). This paucity of empirical data is also related to the typical lack of an integrated, long-term urban freight policy.

For that reason, we conducted a study on urban freight transport characteristics and explored the potential impact of urban freight regulatory measures on transport emissions in Novi Sad. We used the available data on urban traffic flows and traffic volume growth factors to estimate the freight vehicle emissions and their projections in the future.

The vehicle activity data were collected and adjusted in order to perform emission evaluation for the external traffic flows. The all-or-nothing method was used for traffic assignment and traffic projections were made for 2015 and 2020. The calculated freight traffic volume in 2009 was 12,324 vehicles per day, leading to a projected annual volume of 3,093,324. The dominant category of vehicles is LDV (61%), compared to the share of HDV (39%). Projected freight traffic volume is 16% and 64% higher in 2015 and 2020, respectively, compared to 2009 (tab. 3).

The Tier 3 methodology from EMEP/EEA emission inventory guidebook was used for emission calculation [22]. According to the results, 96.50% of total estimated emission originating from freight vehicle movement in external traffic is attributed to CO_2 and 97.23% to CO_2e emissions. It is estimated that the transit freight participates in external freight traffic air pollution by about 47%.

The first important finding of the study is that the analysis of gas emissions indicated an overall positive effect of the regulative measure. Still, the total amount of the emissions heavily increase, so this particular measure is not enough to reach the ambitious EU strategy goals concerned with sustainable urban freight transport. The presented research shows that HDVs are characterized by much higher fuel consumption, compared to the share in total vehicle number, and they are the main contributors to the GHG emissions, as well as to the most of the pollutant emissions. However, their impact is not the same for all observed emissions (fig. 4).

Further, although the analysis of particular gas emissions reveals expected overall positive effects of the fleet renewal in most of cases, some negative impacts of restrictive measures one gas emissions were also recorded. We defined two different scenarios for future emission projections-DoN and VTR-whereby the former assumes no changes in future freight vehicle structure in the traffic volume, while the later considers the implementation of the engine technology restrictive measures by city planners. The adopted restrictive measures are considered reasonable and realistic, as they incorporate the entry restrictions into the city area for freight vehicles with technology lower than Euro I and Euro II in year 2015 and 2020, respectively.

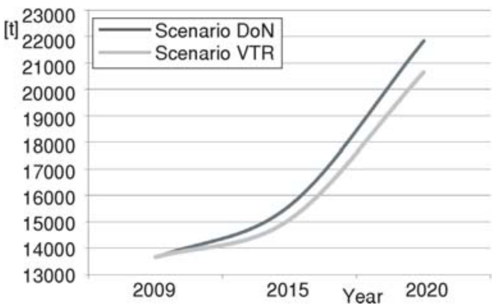

Figure 5. Emission trends for DoN and VTR scenarios

The results of the projected traffic emissions for 2015 and 2020 are rather alarming, whether the restrictive measures are applied or not. Namely, traffic volume growth in the future significantly affects the total freight transport emission levels (fig. 5). The average emission quantity for Scenario DoN in year 2015 increases by around 14% compared to 2009, with further 40% increase in 2020 compared to 2015. Consequently, the estimated total pollutant emissions for DoN Scenario in 2020 will increase by 60% compared to 2009. This trend is certainly far away from "zero emissions". Therefore, the comprehensive set of measures toward sustainable transport EU targets should be seriously considered by city authorities in planning freight transport policy in the imminent period. The fleet renewal could be a useful, but not the single tool to reach given targets. VTR Scenario slightly mitigates the total emission growth, so that total emissions in 2015 and 2020 will be 4% and 9% lower (respectively), compared to DoN Scenario (see fig. 5).

In terms of emissions, the transit freight flows in the external freight traffic play the most important role in air pollution (46% on average). The introduction of regulatory measures assumed in VTR Scenario indicates the positive effects and slightly mitigates the total emission growth (see fig. 5), so that the total emissions in 2015 increase by only 10% relative to 2009 (–4% compared to DoN) and by 37% in 2020 relative to 2015 total emissions (–3% compared to DoN). Consequently, the estimated total emissions for VTR Scenario increase by 51% in 2020 relative to 2009, and are 9% lower than those estimated by DoN Scenario.

Table 5 presents the relative impact of regulatory measures implementation on particular gas emissions. More precisely, it indicates a change in the particular gas emissions resulting from the implementation of described regulatory measures. Note that there is no difference between two scenarios for year 2009, because this year represents the base year for calculations and projections in the absence of any regulative measures. In contrast, projected restrictions in 2015 and 2020 reveals different changes in particular gas emissions. Positive changes are reflected in values with negative sign, and negative changes correspond to the values showing increase in particular gas emissions (dark shaded cells) in tab. 5. Positive effects of future regulations are expressed as higher reduction of emissions in 2020 compared to 2015. It is evident that the implementation of these regulative measures has an overall positive effect on the emission of most pollutant gases.

Table 5. The impact of regulatory measures implementation on particular gas emissions per trip type (Scenario VTR compared to Scenario DoN)

Emision [t]	2009			2015			2020		
	Origin	Destin.	Transit	Origin	Destin.	Transit	Origin	Destin.	Transit
CO_2	0.00% (no change in base year)			0.48%	–0.14%	–5.63%	–3.22%	–3.35%	–5.53%
CO				–38.01%	–50.41%	–45.79%	–56.67%	–69.99%	–63.61%
CH_4				–55.48%	–55.06%	–43.62%	–71.96%	–71.97%	–67.43%
NO_x				–28.40%	–40.22%	–30.49%	–26.96%	–34.72%	–30.02%
NO				–31.18%	–42.47%	–31.96%	–30.12%	–37.17%	–31.38%
NO_2				–7.14%	–23.15%	–19.45%	–4.22%	–16.52%	–20.07%
NH3				225.20%	223.37%	164.46%	355.60%	353.90%	266.23%
N_2O				27.22%	26.87%	23.96%	21.43%	20.99%	9.05%
VOC				15.73%	–73.93%	–64.58%	–6.04%	–82.41%	–77.36%
NMVOC				17.86%	–75.30%	–66.42%	–4.46%	–83.17%	–78.25%
$PM_{2.5}$				41.42%	–57.84%	–50.45%	–9.07%	–59.21%	–63.07%
EC				60.72%	–50.57%	–44.09%	11.15%	–49.68%	–56.71%
OM				5.43%	–72.71%	–65.34%	–50.84%	–74.84%	–74.41%
SO_2				0.45%	–0.17%	–5.65%	–3.25%	–3.39%	–5.55%

However, although the total emission is lower in VTR Scenario, the estimated emission of ammonia ($NH_{3)}$ and nitrous oxide (N_2O) is higher compared to DoN Scenario. The negative correlation between restrictive measures and these two gases emission is the consequence of the catalytic converter application in the exhaust systems of vehicles. Although it is not toxic to the human health at ambient air concentrations, N_2O represents a major greenhouse gas. According to the Kyoto Protocol GWP indicators it has 296 times more impact "per unit weight" than carbon dioxide. Although the contribution of N_2O to the total emission of freight vehicles in external flows in Novi Sad is small, tab. 5 indicates a rising trend in estimated N_2O emissions for the next 10-year period, regardless of the restrictive measure implementation by the city authorities in the future.

Total NH_3 emissions from freight vehicles in external flows in Novi Sad reveal similar trend. Ammonia (NH_3) is a toxic gas that contributes to secondary aerosols and can have an adverse impact on the local environment. Furthermore, it is readily transported in the atmosphere and, as it can acidify land and surface waters, its negative effects can affect even remote ecosystems. Although this emission contribution to the total emission from freight vehicles is also small, it has an upward trend in the future. However, the key difference is that ammonia represents contributor to haze/smog in urban areas, which pauses a threat to human health, leading to an increased rate of respiratory and heart diseases.

The increase of particular gases emission from origin trips is the consequence of the cold start emissions. Still, there are indications that the implementation of regulatory measures will have positive impact on emissions in the distant future.

In order to gain a better insight into the reasons for growing emissions of NH_3 and N_2O, we analyzed these emissions with respect to each vehicle category. The main results are shown in tab. 6. It can be noted that HDV activity is not the cause for the rising trend of these two gases emission. It seems that the LDV (gasoline and diesel) represent the main sources of N_2O emission growth and gasoline powered LDV are the main cause of the increase in NH_3 emissions. There is even a 11.50% reduction in NH_3 emissions in 2015 and 8.35% reduction of N_2O emissions from diesel HDV. The main contributors to this increase in NH_3 emissions are the gasoline powered LDV, with. ~317% growth in 2015 compared to 2009, and around 500% in 2020 compared to 2015. Similarly, LDV (gasoline and diesel) represent the main sources of N_2O emission growth from 0.08 t to 0.11 t in 2015 and from 0.13 t to 0.19 t in 2020.

Table 6. The relative impact of regulatory measures on NH_3 and N_2O emissions per vehicle category (Scenario VTR compared to Scenario DoN)

Emision [t]	2009			2015			2020		
	LDV Gasoline	LDV Diesel	HDV Diesel	LDV Gasoline	LDV Diesel	HDV Diesel	LDV Gasoline	LDV Diesel	HDV Diesel
NH_3	0.00%			317.48%	47.55%	–11.50%	498.41%	0.00%	0.00%
N_2O				69.38%	17.59%	12.28%	13.29%	117.32%	–8.35%

The use of catalytic converters on light duty vehicles has contributed to decrease in most gases emission. However, three-way catalyst converters are the cause of higher ammonia emissions from motor vehicles. Therefore, fleet renewal – natural and due to regulative measures implementation – results with higher amounts of NH_3 emission. Indeed, the diesel engine contribute significantly to ammonia concentrations [33]; that explains the reduction of NH_3 emission from diesel powered engines (tab. 6). However, despite the large percentage increase in emissions of N_2O and NH_3, the emitted quantities are still not worrying considering the absolute values of N_2O and NH_3 emission quantities for the year and the observed area (tab. 4).

Although this research reveals some interesting results, it also suffers from certain limitations. As the all-or-nothing assignment methodology assumes the usage of the shortest trip path, it cannot account for congestion effects and subjective judgments of individual drivers. The approximations made due to the lack of data pertaining to different vehicle engine types decrease the level of empirical data accuracy. However, they do not affect the main research results and outputs on impact of restrictive measures on urban freight transport air emissions.

Also, due to a lack of more precise data, the fleet renewal forecast may be a cause of a limited practical value of the calculation results. The research presented here should be repeated by city authorities with more comprehensive and more accurate data before the implementation of particular urban freight policy measures. Further research on urban freight transport in Novi Sad has also to comprise the data on internal freight flows. Finally, the applied COPERT IV method also has a set of limitations that impact on the accuracy of the presented findings [31].

It is important to obtain the more comprehensive database on both HDV and LDV, as this would allow us to explore more in-depth empirical results on the freight flows in Novi Sad. The pickups and LDV are expected to be the dominant group in internal freight flows, thus significantly contributing to the total freight emissions in the future. Currently, the restrictive freight transport measures are implemented only in the inner city (city ring), and applied to the vehicles with more than 5 tons weight limit [14]. Therefore, this is an additional reason for obtaining a better insight into the potential environmental impact of implemented or planed regulatory measures. Further research that overcomes the current weaknesses may strongly contribute to the development of sustainable freight city planning.

Conclusions

Understanding and mitigating the growing negative environmental impact of freight transport is particularly important for developing countries, which are characterized by an increasing level of urbanization and motorization, while the related environmental concerns lack the funds and attention they deserve.

Estimation of air pollution has recently become increasingly important for urban transport planners. The research reported in the literature has been firstly focused on urban passenger transport and its impact on air pollution, but today there is the rising interest for the impact of urban freight transport on pollution and environment on a whole. Therefore, we have performed a study on impact of freight transport on air pollution using the case of Novi Sad, in order to estimate the air emissions of external freight flows and the impact of some related regulatory measures on emission reduction in the future.

The study yielded several interesting research findings. The fleet renewal as a regulatory measure has an overall positive impact on urban freight transport emissions. Still, the total amount of the same emissions heavily increase, so this particular measure is not enough to reach the ambitious EU strategy goals concerned with sustainable urban freight transport. The presented research results indicate a clear need for introduction of explored and other measures related with sustainable urban freight transport policy in Serbian environment.

Further, although the analysis of particular gas emissions reveals expected overall positive effects of the fleet renewal in most of cases, some negative impacts of restrictive measures on gas emissions were also recorded. The revealed complex impact of restrictive measures on urban freight air pollution indicates that urban freight transport planning and modeling requires comprehensive database, clear goals and higher priority of environmental criterion in traffic planning. The set of indicators should be also developed according to the specific traffic planners' measures and targets, their cost assessment, as well as according to the long-term planning, strategic action plans and EU recommendations.

The main limitation of the results presented in this work is related to the applied methodology and a lack of data necessary to perform the more precise calculation. The set of approximations was introduced due the absence of a database needed for the completion of the presented research. However, even though the absence of empirical data influences the accuracy of absolute values of calculated emissions in the external flows in Novi Sad, it does not affect the main research results. A comprehensive urban freight database is a necessary precondition for sustainable freight transport planning and development.

The revealed results and subsequent recommendations may be inspiring for scholars, urban transport planners, policy makers and practitioners. This study indicates the directions for future research and might be useful in the development of sustainable urban freight transport policy. Practitioners may get a valuable insight into the current trends related to sustainable urban freight transport development and take timely and effective steps towards adjusting the fleet structure and management in order to meet more stringent environmental requirements.

References

[1] Papić, V., *et al* ., Determination of Emissions of Gaseous Pollutants from Road Transport Using COPERT IV Model of the Environmental European Agency (in Serbian), Institute of the Faculty of Transport and Traffic Engineering, University of Belgrade, Belgrade, 2010
[2] ***, Commission of the European Communities, COM (2005) 718 Final, Communication from the Commission to the Council and the European Parliament on Thematic Strategy on the Urban Environment, Brussels, 2006
[3] Benjelloun, A., *et al*., Toward a Taxonomy of City Logistics Projects, Publication CIRRELT, Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation, University of Montreal, Montreal, Canada
[4] ***, European Commission, COM (2011) 144 Final, Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System, Brussels, 2011
[5] Taniguchi, E., *et al* ., Visions for City Logistics, *Proceedings*, 3rd International Conference on City Logistics, Madeira, Portugal, 2003, pp. 1-16
[6] Filippi, F., *et al* ., Delle Site, P., Ex-Ante Assessment of Urban Freight Transport Policies, *Procedia Social and Behavioral Sciences 2*, The Sixth International Conference on City Logistics, 2010, Vol. 2, Issue 3, pp. 6332-6342
[7] ***, BESTUFS: Good Practice Guide on Urban Freight. BESTUFS Consortium, 2007, www.bestufs.net.
[8] Browne, M., *et al* ., Literature Review WM9: Part I – Urban Freight Transport, Transport Studies Group, University of Westminster, London, 2007
[9] ***, The Government of the Republic of Serbia, National Strategy of Sustainable Development (in Serbian), Belgrade, 2008
[10] Jović, J., Djorić, D., Application of Transport Demand Modeling in Pollution Estimation of a Street Network, *Thermal Science, 13* (2009), 3, pp. 229-243
[11] Stojanović, Dj. *et al* ., The Development of Eco-Friendly City Logistics (in Serbian), *Ecologica, 19* (2012), 66, pp. 195-200
[12] ***, Statistical Office of the Republic of Serbia, 2011 Census of Population, Households and Dwellings in the Republic of Serbia – First Results, Belgrade, 2011
[13] Public Enterprise for City Construction and Development, Novi Sad, Serbia, http://ns.zigns.rs/bn_index.cfm
[14] Stojanović, Dj, ., Veličković, M., The Impact of Freight Transport on Greenhouse Gasses Emissions in Serbian Cities – The Case of Novi Sad, *Metalurgia International, 17* (2012), 6, pp. 196-201
[15] Giannouli, M., *et al*., Impact of European Emission Control Strategies on Urban and Local Air Quality, *Atmospheric Environment, 45* (2011), 27, pp. 4753-4762
[16] D'Angiola, A., *et al*., On-Road Traffic Emissions in a Megacity, *Atmospheric Environment, 44* (2010), 4, pp. 483-493

[17] ***, City Planning Institute – Public Enterprise "Urbanizam", Traffic Study of Novi Sad with the Dynamics of Traffic Regulation – NOSTRAM (in Serbian), Novi Sad, Serbia, 2009
[18] ***, Centar for Roads of Vojvodina, General Project of Building Petrovaradin Ring Road (in Serbian), Novi Sad, Serbia, 2010
[19] ***, General Master Plan for Transport in Serbia Final Report – Annex I (in Serbian), Report No. 05SER01/04/016, Serbia, 2009
[20] Manojlović, A., *et al*., Fleet Renewal: An Approach to Achieve Sustainable Road Transport, *Thermal Science, 15* (2011), 4, pp. 1223-1236
[21] Sheffi, Y., Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods, Massachusetts Institute of Technology, Cambridge, Mass., USA, 1985
[22] Ntziachristos, L., Samaras, Z., EMEP/EEA air Pollutant Emission Inventory Guidebook, European Environment Agency, 2009
[23] Saija, S., Romano, D., A Methodology for the Estimation of Road Transport air Emissions in Urban Areas of Italy, *Atmospheric Environment, 36* (2002), 34, pp. 5377-5383
[24] Waldron, D., *et al* ., 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Chapter 3: Mobile Combustion, Volume 2: Energy, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan, 2006
[25] Kousoulidou, M., *et al* ., Road-Transport Emission Projections to 2020 in European Urban Environments, *Atmospheric Environment, 42* (2008), 32, pp. 7465-7475
[26] Gkatzoflias, D., *et al* ., Computer Programme to Calculate Emissions from Road Transport - User Manual, European Environment Agency, 2007
[27] Kassomenos, P., *et al* ., Estimation of Daily Traffic Emissions in a South-European Urban Agglomeration during a Workday. Evaluation of Several "What if" Scenarios, *Science of the Total Environment, 370* (2006), 2-3, pp. 480-490
[28] Smit, R., *et al* ., Improved Road Traffic Emission Inventories by Adding Mean Speed Distributions, *Atmospheric Environment, 42* (2008), 5, pp. 916-926
[29] Khoshyarana, M., *et al* ., A Dynamic Model for Assignment and Cold Start Emission, *Procedia Social and Behavioral Sciences, 20* (2011), pp. 714-722
[30] Onga, H., *et al* ., A Review on Emissions and Mitigation Strategies for Road Transport in Malaysia, *Renewable and Sustainable Energy Reviews, 15* (2011), 8, pp. 3516-3522
[31] Andre, M., Hammarstrom, U., Driving Speeds in Europe for Pollutant Emissions Estimation, *Transportation Research Part D, 5* (2000), 5, pp. 321-335
[32] Houghton, J., *et al* ., Climate Change 2001: The Scientific Basis, Volume I, IPCC Third Assessment Report, Cambridge University Press, Cambridge, UK, 2001
[33] Kean, J. A., *et al* ., On-Road Measurement of Ammonia and other Motor Vehicle Exhaust Emissions, *Environmental Science and Technology, 34* (2000), 12, pp. 3535-3539

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