FLEET RENEWAL: AN APPROACH TO ACHIEVE SUSTAINABLE ROAD TRANSPORT

by

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With more stringent requirements for efficient utilisation of energy resources within the transport industry a need for implementation of sustainable development principles has appeared. Such action will be one of competitive advantages in the future. This is especially confirmed within the road transport sector. A methodology implemented in public procurement procedures for fleet renewal regarding the calculation of road vehicles' operational lifecycle costs has been analysed in detail in this paper. Afore mentioned calculation comprises the costs for: vehicle ownership, energy, carbon dioxide and pollutants emissions. Implementation of this methodology allows making the choice of energy efficient vehicles and vehicles with notable positive environmental effects. The objective of the research is to assess the influence of specific parameters of vehicle operational lifecycle costs, especially energy costs and estimated vehicle energy consumption, on vehicle choice in the procurement procedure. The case of urban bus fleet in Serbia was analysed. Their operational lifecycle costs were calculated and differently powered vehicles were assessed. Energy consumption input values were defined. It was proved that defined fleet renewal scenarios could influence unquestionable decrease in energy consumption.

Key words: *energy efficiency, fleet renewal, sustainable procurement, operational lifecycle costs*

1. Introduction

The vision of a sustainable and competitive transport system of the European Union understands becoming independent (or even better to stop depending) on petroleum without jeopardising its efficiency and mobility [1]. The utmost objective of the European transport policy is to assist in implementing a system promoting economic development, improving competitiveness and offering higher level of service regarding mobility with rational and efficient utilisation of resources [2, 3]. This means that transport should not only consume less energy, but as well consume renewable

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energy, better use the infrastructure, decrease its negative impact on the environment and key natural resources such as: water, land and ecosystems.

Development of the transport system, and especially road transport, must rely on improving energy efficiency of vehicles, as well as on development and introduction of sustainable fuels and propulsion systems [4]. There are several approaches to influence the transport operators to renew their fleets with energy efficient vehicles having lower exhaust emissions. One of them is the implementation of EU Directives related to the use of energy from renewable sources [5] and those related to clean and energy-efficient road transport vehicles [6]. They define the implementation of the calculation of vehicles' operational lifecycle costs including energy and emission costs, regarding pollutant and CO_2 emissions, during the vehicle choice within green public procurement procedures.

In 2009, European Union spent 1900 billion EUR on public procurements of products and services, which accounts for around 16% of the Gross Domestic Product (GDP) of the European Union [7]. Public procurements represent an essential and leading market for the introduction of new technologies because of its high capacity to instruct industry, society and individuals with novel technologies [8-10]. Therefore, it is considered that an important role in fleet renewal should be given to the public procurement system. Vehicles purchased through public procurement are used every day and are visible to large number of individuals. This will influence other vehicle users to apply the same pattern while purchasing a new vehicle. In order to avoid market disturbances, unique procurement rules should be specified. One of the rules is concerning the methodology of vehicles' operational lifecycle costs calculation.

In this paper the parameters of the vehicle operational lifecycle costs calculation methodology will be analysed, including the energy and pollutants' emission costs, in the case of fleet renewal by public procurement of urban buses, with the objective of attaining principles of sustainability and in line with local sustainable development [11]. In order to offer a solution to the defined problem, the influence of different scenarios of urban bus fleet renewal in Serbia on operational and total energy costs and vehicle fleet pollutants' emissions were considered in the period 2010-2019.
The results of the calculation of vehicles' operational lifecycle costs are then presented. Subsequently, pollutants' emissions and total energy consumption were estimated by means of the COPERT IV model for selected scenarios.

The basis of the research presented in this paper lies in the fact that vehicle exhaust emission reduction (NO_X, HC, PM, and CO_2) can be achieved by various measures, where one of the most important is the fleet renewal. In order to confirm this statement, various scenarios of bus fleet renewal have been set and for all cases amounts of pollutants emitted have been calculated.

The paper illustrates the Serbian bus fleet development based on the fleet renewal, which allows forecasting and measuring its impact on reduction of pollutants' emissions and energy efficiency. The objective of the research is to assess the influence of certain parameters of vehicle operational lifecycle costs, especially energy costs and estimation of vehicle's energy consumption, on choice of vehicles in the procurement procedure. Therefore, we have first presented the relations between sustainable procurement and energy efficiency of vehicles. Then, the case of urban bus fleet renewal in Serbia was presented. Subsequently, the methodology for operational lifecycle costs assessment is elaborated for differently powered vehicles in public procurement procedures. Finally, the results of vehicle fleet renewal scenarios were analysed and relevant conclusions were given.

Some pollutants' emissions reductions as well as energy efficiency improvements have been achieved solely by implementation of Euro emission standards. Further improvement requires elaborate engagement in wider - national fleet renewal. However, trend of existing vehicle fleet renewal with highly developed or low emission vehicles varies over the years.

2. Sustainable procurement and vehicle energy efficiency

The incentive for introduction of cleaner, energy efficient vehicles by means of the public procurement procedure has the objective to rely more importantly on the market of those vehicles in order to gradually improve the transport industry sector features by reducing its negative environmental impact. The focus of analysed public procurements is the purchasing of road vehicles based on contracts where one contractual party was the public administration, while the other is an operator having the public service obligation. The method for reaching the objective is in incorporating all those elements of vehicle operational lifecycle costs coupled with the energy consumption, carbon dioxide (CO_2) nitrogen oxides (NO_X), hydrocarbons (HC) and particulate matter (PM) emissions into criteria for vehicle procurement. Besides afore mentioned, some other negative environmental impacts could be also considered. If there is a possibility and if appropriate, the stated criteria could be complemented by a requirement for energy consumption specification within the documentation for procurement of road vehicles and for all other considered criteria, as well as additional negative environmental impacts [12].

The system of sustainable public procurements should be defined as responsible allocation of public funds on products and services inducing certain sector's sustainable development. Sustainable procurement considers the following criteria for the choice: only the really necessary is procured, and only those products and services having minor negative environmental impact are provided, while at the same time it is accounted for social and economic impacts of the realised procurement [13]. Upon [14, 15] a sustainable procurement is the procurement of products and services supposing that a special attention is devoted to:

- strategies avoiding unnecessary consumption, while at the same time managing the needs and requirements for products and services that will incite a sound and rational consumption,
- reducing negative environmental impact to the lowest possible level during the operational lifecycle period,
- social responsibility of the provider including to respect his obligations regarding his employees, and
- overall value of the products or services over the entire operational lifecycle period, and not only with initial procurement costs.

In this sense, in the European Union, within the last decade, a particular attention has been devoted to procurements of cleaner and energy efficient vehicles, as well as procurement of alternatively fuelled vehicles (AFV) [16]. The market elements of such vehicles have been studied in detail, as well as all interested parties on the market: vehicle manufacturers, users, *i.e.* vehicle owners and public administrations.

The sustainable public procurement procedure in essence is not at all different from regular procurements (not public). Both procurements are composed of the same phases: formulation of the contract matter, definition of technical specifications, selection of best bids, selection of the best provider, contract management during the contractual period and establishment of partner collaboration with vehicle supplier [13, 14].

In every phase of the sustainable procurement, procedures to check the conformity with sustainable development principles are applied. Primary and crucial phase in the procurement cycle is determination of realistic needs for vehicles. The choice of necessary vehicles' features involves selection of parameters within the methodology for calculation of vehicle operational lifecycle costs. Realisation of the procurement procedure, *i.e.* vehicle assessment and choice are susceptible to those defined elements within the adopted procurement approach, which means that the vehicle with minor overall operational lifecycle costs involving costs of operation, energy and pollutants' emissions is chosen. After the choice of the vehicle and during the operation it is provided that the vehicle operation allows minimising negative environmental impact and being energy efficient. In the final phase of the procurement cycle, the vehicle utilisation in the previous operational period is analysed, which will be used in questioning the needs for vehicles and introducing eventual modifications in the applied procurement approach.

It is essential to note the difference between the Green public procurement and Sustainable public procurement [7]. The Green public procurement involves the elements related solely to the environmental impact and it is linked to [6], while the Sustainable public procurement involves economic, social and environmental parameters and demands a more complex approach to the procurement realisation.

In the subsequent case study, methodologies for calculation used in green procurement and sustainable procurement will be analysed, as well as their impact on urban bus fleet renewal.

3. Case study of Serbia

The bus fleet of the Republic of Serbia consists of approximately 8,700 buses in 2010, with very heterogeneous structure in terms of purpose, capacity and age. Out of the previously mentioned, the fleet of urban buses consists of around 4,100 buses. In the period between 1990 and 2009, the number of registered urban buses did not change importantly and it was at the same level of around 4,000 buses throughout the entire period [17].

In order to determine the measures that would affect the reduction of pollutants' emission and improvement of energy efficiency from the bus fleet in Serbia, two scenarios of the bus fleet renewal have been set for the following period [18]. Scenarios were defined to include a different share of new and used buses in the bus fleet renewal. The percentage of renewal for the chosen period was determined based on bus fleet structure change between 2000 and 2009. The scenarios were determined so the total number of city buses remains the same in the future while only the fleet structure changes. It should also be noted that the oldest buses are to be written-off during the renewal. In order to predict the trend of pollutant's emission and energy consumption in the period from 2010 to 2019, the analyses of bus fleet development, period of introduction and duration of implementation of Euro standards were taken into account, as well as other relevant regulations related to vehicle technology and vehicle procurement. The scenarios were defined upon market conditions, operators' development plans and tenders for public procurement of passenger transport service in Serbian cities in the referred period. Within bus fleet renewal projections, buses complying with the Enhanced

Environmental Friendly Vehicle (EEV) technology were taken into account. Bearing in mind that in Serbia from unconventional *i.e.* alternative fuels, only biodiesel and compressed natural gas powered buses are available, therefore the considered fleet renewal scenarios incorporated only buses using those mentioned fuels.

Scenario S1

The first scenario is determined based on previous trends of bus fleet renewal. The share of new (65%) and used buses (35%) within this number were adopted. The renewal plan is shown in the tab. 1 part S1. Within this scenario, three options have been considered:

- S1D, fleet renewal made by diesel buses, complying with EURO V standards until 2015 and subsequently the fleet is renewed by new EEV vehicles,
- S1BD, fleet renewal made by biodiesel EEV buses, and
- S1CNG, fleet renewal made by compressed natural gas (CNG) EEV buses.

In 2019 the estimated number of new buses will be 1,256.

Scenario S2

The second scenario was established as to reflect the bus fleet renewal with new buses only. The renewal plan is shown in the tab. 1 part S2. Within the second scenario, three options have been considered:

- S2D, fleet renewal made by diesel buses, complying with EURO V and EEV standards,
- S2BD, fleet renewal made by biodiesel EEV buses, and
- S2CNG, fleet renewal made by compressed natural gas (CNG) EEV buses.

In 2019 the estimated number of new buses will be 1,448.

The urban bus fleet structure in the period between 2010 and 2019, for all scenarios is shown on figures 1-6.

Table 1. Urban bus fleet renewal scenarios in the period 2010-2019

Scenario		Year									
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
S1	Number of new buses	-	107	47	102	96	146	155	182	220	201
	Total number of procured new buses in the fleet	-	107	154	256	352	498	653	835	1055	1256
	Other	4093	3986	3939	3837	3741	3595	3440	3258	3038	2837
	Serbian urban bus fleet (Total)	4093	4093	4093	4093	4093	4093	4093	4093	4093	4093
S2	Number of new buses	-	167	73	156	148	146	155	182	220	201
	Total number of procured new buses in the fleet	-	167	240	396	544	690	845	1027	1247	1448
	Other	4093	3926	3853	3697	3549	3403	3248	3066	2846	2645
	Serbian urban bus fleet (Total)	4093	4093	4093	4093	4093	4093	4093	4093	4093	4093

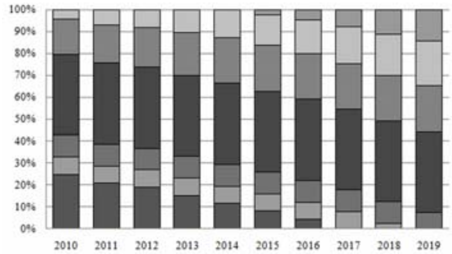

Figure 1. Fleet structure for the scenario S1D in the period 2010-2019

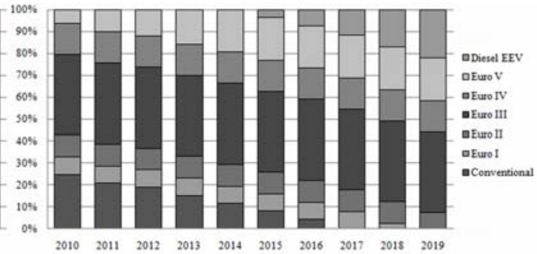

Figure 2. Fleet structure for the scenario S2D in the period 2010-2019

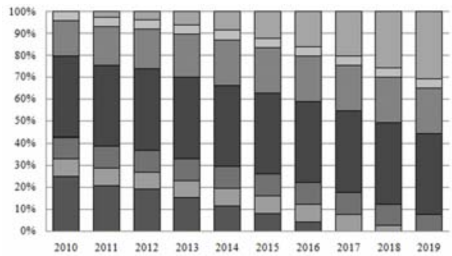

Figure 3. Fleet structure for the scenario S1BD in the period 2010-2019

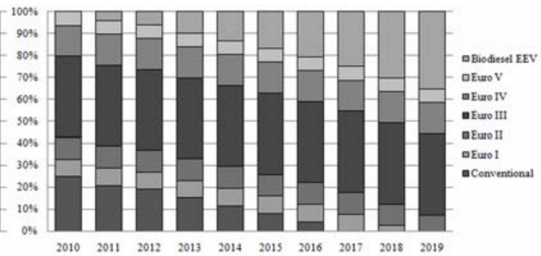

Figure 4. Fleet structure for the scenario S2BD in the period 2010-2019

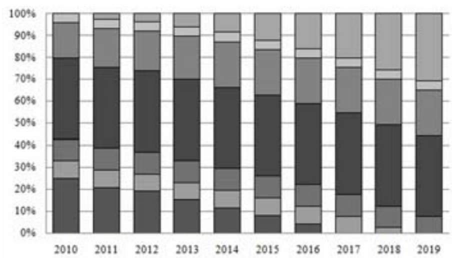

Figure 5. Fleet structure for the scenario S1CNG in the period 2010-2019

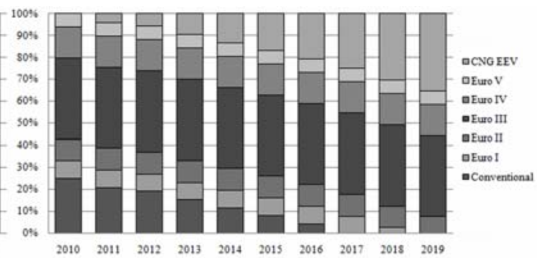

Figure 6. Fleet structure for the scenario S2CNG in the period 2010-2019

In 2019 newly purchased (*i.e.* new) vehicles will be around 30.7% of the fleet upon scenario S1, while upon scenario S2 they will make 35.4%.

3.1 Calculation significance

The methodology for calculation of bus operational lifecycle costs used in the public procurement procedures was analysed in detail in this paper. The calculations have been realised for above mentioned scenarios and urban buses that are powered by:

- diesel,
- biodiesel B100 (pure or 100% biodiesel),
- compressed natural gas.

The features of the buses of different manufacturers that were used for calculations are shown in the following tab. 2. The data on pollutants' emissions have been acquired by bus distributors on the territory of Serbia. The pollutants' emissions are relating to type approval values.

Table 2. Urban buses features applied in the calculations

Fuel	Engine power [kW]	Emission class	NOx [g/km]	HC [g/km]	PM [g/km]	CO_2 [kg/km]
Diesel	280	Euro V	5.725	0.013	0.025	1.237
Diesel	265	EEV	3.225	0.013	0.019	1.237
Biodiesel B100	235	EEV	3.225	0.025	0.019	0.688
Compressed natural gas	225	EEV	2.288	0	0.003	0.925

The calculations incorporate assessments of consumed energy, total pollutants' emissions and vehicle operational lifecycle costs established in:

- green public procurement according to [6], for one vehicle;
- sustainable public procurement: the authors of this paper have calculated by applying the model COPERT IV the consumed energy and pollutants' emissions [19] as well as costs of bus operation, energy and pollutants' emission for urban bus fleet for all scenarios.

Finally, the costs of operation for all scenarios have been analysed depending on the unit fuel price with and without excise duty. The calculation is based on an average bus operational lifecycle of 10 years and a mileage of 800,000 km.

3.2 Green public procurement results

According to green public procurement [6] the calculation of lifecycle environmental performance is used to compare vehicles and as a criterion for vehicle selection in the public procurement procedure referring to the consumed energy and pollutants' emissions or else to monetary values corresponding to lifecycle emissions to be included in the procurement choice.

The vehicle fuel consumption per kilometre travelled is expressed in energy consumption units per kilometre. For this calculation, a single (unique) unit energy price is used. For this unit value, a lower price between unit price of petrol and diesel (the market price ex taxes) is adopted. In April 2011 in Serbia the production petrol price (unleaded petrol "BMB" 95 octanes) was 0.515 EUR/l, meanwhile the eurodiesel unit price was higher and amounted 0.688 EUR/l. accordingly, for the calculation has been selected the unit energy costs of 0.0161 EUR/MJ, having in mind that the petrol energy value is 32 MJ/l. The fuel consumption is obtained from bus manufacturers. Energy values of alternative fuels are shown in [6, 21].

Total consumed energy, pollutants' emissions and their monetary values are shown hereafter in tab. 3. In total costs, the major value is for the costs of energy and CO_2 emissions. Buses powered by biodiesel have the smallest monetary value of emissions throughout the operational lifecycle, while the CNG powered buses have the highest monetary value because of their high energy consumption.

Table 3. Consumed energy, total pollutants' emissions and monetary value of energy and pollutants according to green procurement requirements, 10 years, 800,000 km

Fuel	Fuel consumption	Energy [GJ]	NO_X [kg]	HC [kg]	PM [kg]	CO_2 [t]	Energy [EUR]	NO_X [EUR]	HC [EUR]	PM [EUR]	CO_2 [EUR]	Total [EUR] (9+10+11+12+13)
1	2	3	5	6	7	8	9	10	11	12	13	14
Diesel Euro V	0.46 l/km	13,248	4580	10	20	990	213,293	20,152	10	1740	29,698	264,892
Diesel EEV	0.46 l/km	13,248	2580	10	15	990	213,293	11,352	10	1310	29,698	255,662
Biodiesel B100	0.49 l/km	12,936	2580	20	15	550	208,270	11,352	20	1310	16,500	237,452
Compressed natural gas	0.60 Nm^3/km	15,840	1830	0	2	740	255,024	8,052	0	174	22,200	285,450

3.3 Sustainable public procurement results

The bus operational lifecycle costs involve ownership costs, fuel costs, maintenance costs, registration costs and insurance. The costs of infrastructure are not included. All of these costs for different considered buses are shown in tab. 4 and represent the research results of the authors. In the survey have been involved: manufacturers, vehicle maintenance and repair centres, and insurance companies in Serbia. The prices vary depending on the vehicle manufacturer and here are shown just the average maintenance, insurance and ownership costs. Cost of ownership represent the difference between the bus basic price ex value added tax (VAT) and the remaining bus value after the adopted lifecycle period of ten years of operation. The estimated remaining value is approximately 15% of the bus purchase value. For the fuel cost calculation the fuel prices paid by operators in April 2011, ex VAT, expressed in EUR according to the average mean exchange rate in April of 1 EUR = 101.5 RSD: for diesel 1.1 EUR/l, biodiesel 0.84 EUR/l and CNG 0.46 EUR/Nm3. The price of diesel includes also the excise duty in the amount of 0.364 EUR/l, while for the compressed natural gas and biodiesel the excise duty is not applied.

Table 4. Urban bus operational lifecycle costs, 10 years, 800,000 km

Fuel and emission level	Bus basic price [EUR]	Maintenance cost [EUR]	Registration and insurance cost [EUR]	Cost of ownership [EUR]	Fuel cost [EUR]	Total costs [EUR]	Total costs, annualised [EUR/year]
Diesel Euro V	200,000	44,000	42,000	170,000	404,800	660,800	66,080
Diesel EEV	200,000	46,000	42,000	170,000	404,800	662,800	66,280
Biodiesel B100	200,000	48,000	42,000	170,000	329,280	589,280	58,928
Compressed natural gas	260,000	65,000	42,000	221,000	220,800	548,800	54,880

The least operational costs, upon present prices, have been attained by the CNG powered buses because of the low price of this fuel. The operational costs of biodiesel powered buses are higher for approximately 7%, and those of diesel powered buses for around 20%. The major part of the total costs is constituted by the energy costs.

The pollutants' (NO_X, HC, PM) and CO_2 emission costs have been calculated for newly purchased vehicles from tab. 1 (in the row Total in the fleet of newly purchased vehicles) for six scenarios and are shown in the tab. 5. The pollutants' emissions are calculated by using the model COPERT IV, while for the calculation, unit prices of pollutants' emission stipulated by the Directive [6] have been applied.

Table 5. Pollutants' emission costs for newly purchased buses [in thousands EUR]

Scenario	Year								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
S1D	450	647	1,076	1,480	2,094	2,745	3,510	4,435	5,280
S1BD	374	538	895	1,230	1,741	2,282	2,918	3,687	4,390
S1CNG	483	697	1,155	1,589	2,247	2,947	3,769	4,761	5,668
S2D	702	1,009	1,665	2,287	2,901	3,552	4,317	5,242	6,087
S2BD	584	839	1,384	1,901	2,412	2,953	3,589	4,358	5,061
S2CNG	753	1,083	1,787	2,455	3,114	3,814	4,634	5,627	6,535

The costs of pollutants' emissions are the lowest for scenarios with biodiesel powered buses (S1BD, S2BD). The highest costs have been obtained for scenarios with CNG powered buses (S1CNG, S2CNG) because of higher CO_2 and NO_X emissions.

The operational costs for the referred period for the fleet of newly purchased buses are shown in following tab. 6.

Table 6. Operational costs of newly purchased buses in the period 2011-2019 [in thousands EUR]

Scenario	Year								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
S1D	7,092	10,207	16,968	23,331	33,007	43,281	55,344	69,925	83,248
S1D PR	*5,653*	*8,136*	*13,525*	*18,597*	*26,310*	*34,499*	*44,115*	*55,738*	*66,357*
S1BD	6,305	9,075	15,086	20,743	29,346	38,480	49,205	62,169	74,014
S1CNG	5,872	8,452	14,049	19,318	27,330	35,837	45,825	57,898	68,929
S2D	11,069	15,907	26,247	36,056	45,733	56,007	68,070	82,651	95,973
S2D PR	*8,823*	*12,680*	*20,921*	*28,741*	*36,454*	*44,643*	*54,258*	*65,882*	*76,501*
S2BD	9,841	14,143	23,335	32,057	40,660	49,794	60,519	73,483	85,328
S2CNG	9,165	13,171	21,732	29,855	37,867	46,374	56,362	68,435	79,466

The least operational costs have been obtained for scenarios with CNG powered buses. In the table are shown also the costs of scenarios S1D and S2D with the fuel costs without excise duty.

Those costs are shown in the table in rows S1D PR and S2D PR and are lower than the operational costs of all other scenarios. Consequently, for example in the case of the scenario S2CNG realisation, the estimated operational costs of this scenario for newly purchased buses in 2019 would be approximately 79.46 million EUR, but the national budget would be shorter for the amount of 22.47 million EUR based on the excise duty that would be earned if the fleet would have been renewed by diesel powered buses.

As for the operational costs, as well as for the total costs including the pollutants' emission costs the minimum value is held by scenario of CNG powered buses (tab. 7). If from the calculation we would exempt the excise duty paid for diesel, the minimum costs would be for scenarios with diesel powered buses. The energy costs have the predominance in the comparison of all the scenarios.

Table 7. Operational costs of newly purchased buses including the pollutants' emission costs in the period 2011-2019 [in thousands EUR]

Scenario	Year								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
S1D	7,542	10,855	18,044	24,810	35,101	46,026	58,854	74,361	88,528
S1D PR	*6,103*	*8,784*	*14,601*	*20,077*	*28,404*	*37,244*	*47,625*	*60,173*	*71,637*
S1BD	6,679	9,613	15,980	21,973	31,087	40,762	52,123	65,856	78,403
S1CNG	6,355	9,149	15,204	20,906	29,578	38,784	49,593	62,660	74,597
S2D	11,771	16,916	27,912	38,343	48,634	59,559	72,387	87,893	102,061
S2D PR	*9,525*	*13,689*	*22,586*	*31,028*	*39,355*	*48,195*	*58,576*	*71,124*	*82,588*
S2BD	10,425	14,982	24,720	33,958	43,072	52,748	64,109	77,842	90,389
S2CNG	9,918	14,254	23,520	32,310	40,981	50,187	60,996	74,063	86,001

The consequence of the lowest price on the fuel market in Serbia and non-existent excise duty imposed to compressed natural gas lead to the minimum annual operational costs for CNG powered buses (54880 EUR) as shown in tab. 8. Including the pollutants' emission costs the biodiesel powered buses costs are higher for 5.1%, while those of diesel powered buses are higher for 18.3% related to CNG powered buses.

Table 8. Annualised operational costs of buses

Fuel and emission class	Operational costs without diesel excise duty [EUR/year]	Operational costs with diesel excise duty [EUR/year]	Operational costs including pollutant costs [EUR/year]
Diesel EURO V	52,482	66,080	70,284
Diesel EEV	52,832	66,280	70,484
Biodiesel EEV	58,728	58,928	62,423
Compressed natural gas EEV	54,880	54,880	59,391

4. Scenario results analysis

Emission of pollutants has been calculated for the reference period and the results of CO_2 and energy consumption for the fleet of 4,093 urban buses are presented hereafter (on figures 7 and 8). For all the scenarios of fleet renewal both CO_2 emission and energy consumption are decreasing. The model COPERT IV of the European Environment Agency has been used for determining the amount of pollutants emitted and energy consumption. For the emission calculation COPERT IV uses a set of categorised input data, including the number of buses according to emission levels, the average annual mileage, the average speed of buses in urban traffic conditions, the average monthly temperature, and the average monthly air pressure. The input data and emission factors are adopted based on the survey that was completed during the project [17] realisation.

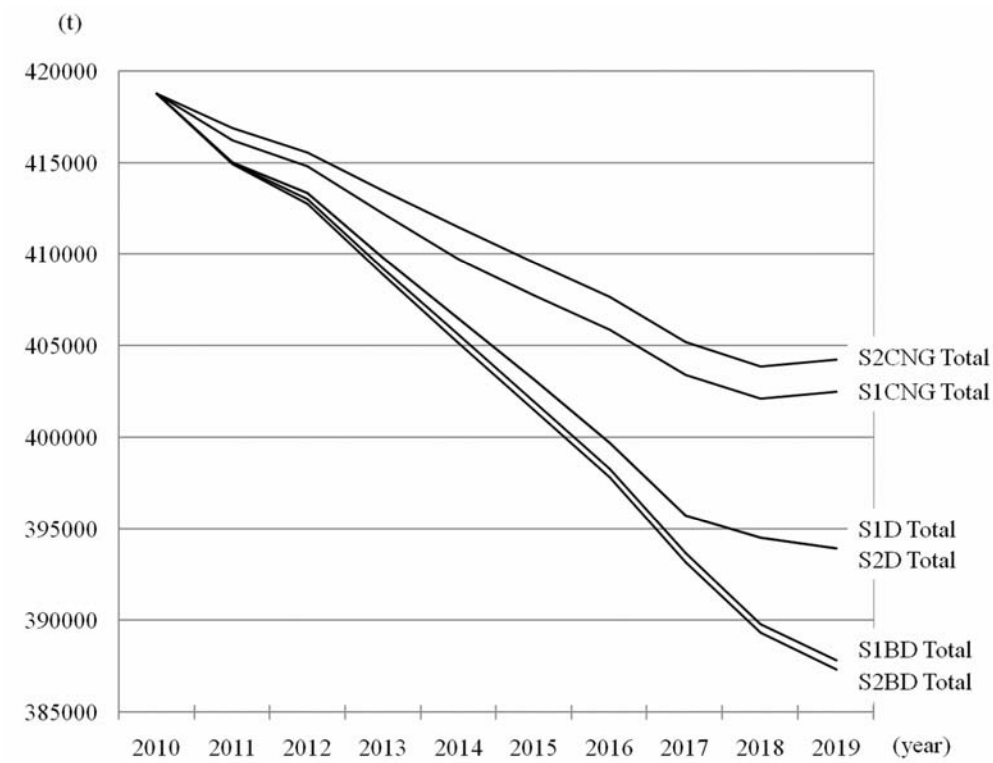

Figure 7. CO_2 emission for different fleet renewal scenarios between 2010 and 2019, 4,093 buses

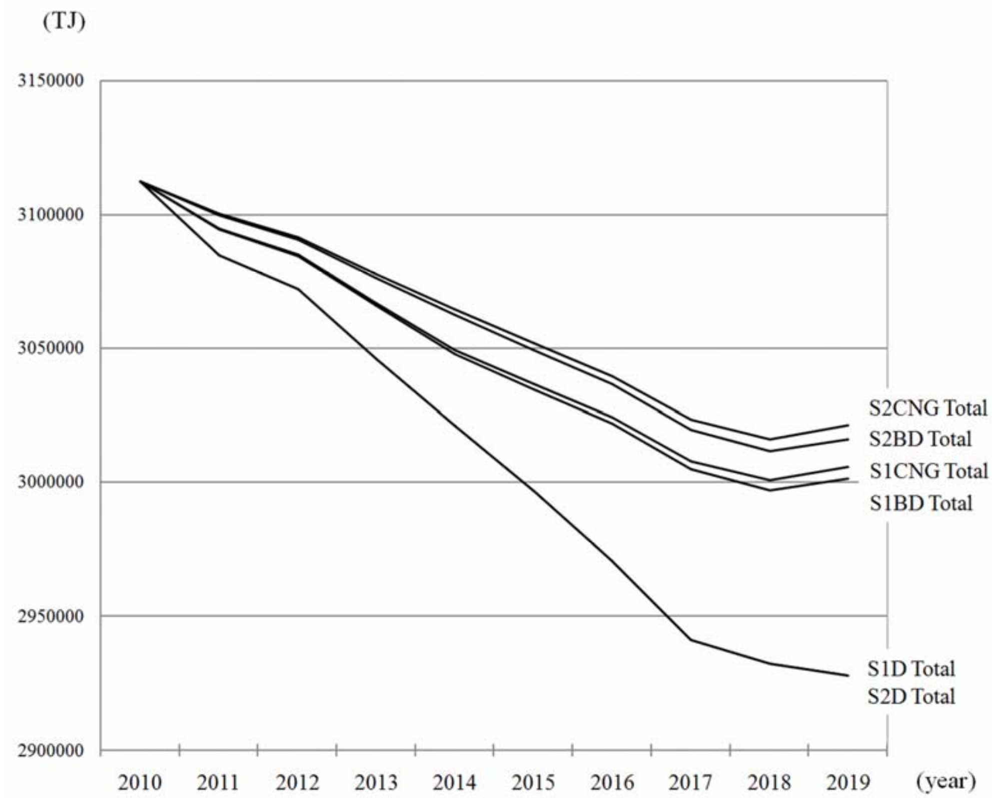

Figure 8. Total energy consumption for different fleet renewal scenarios between 2010 and 2019, 4,093 buses

For selected fleet renewal scenarios, regarding the base year 2010, the CO_2 emission is the most reduced for scenarios of fleet renewal with biodiesel powered buses. As for scenario S2BD this reduction amount is 7.52% (shown in tab. 9). For the scenario S2CNG the CO_2 emission reduction compared to 2010 is 14,516 tonnes. The emissions of NO_X, HC and PM in the referred period are decreasing for all scenarios. The emission of NO_X importantly decreases and the most for the scenario S2BD, with 46.42%. The emission of HC in the final year 2019 is reduced from the initial 376 t down to 104 t for biodiesel scenarios and 105 t for diesel scenarios. The reduction of total PM emission for all scenarios is around 60%. The total energy consumption is the lowest for the scenarios with diesel powered buses (S1D, S2D), and highest for scenarios with CNG and biodiesel powered buses (S2CNG, S2BD), because of the rising share of CNG and biodiesel buses in the fleet structure.

Table 9. Pollutants' emission and energy consumption ratios in comparison with base year 2010

Year	2010	2019											
	Total [t]	S1D Total [t]	(3-2)/2 [%]	S1BD Total [t]	(5-2)/2 [%]	S1CNG Total [t]	(7-2)/2 [%]	S2D Total [t]	(9-2)/2 [%]	S2BD Total [t]	(11-2)/2 [%]	S2CNG Total [t]	(13-2)/2 [%]
1	2	3	4	5	6	7	8	9	10	11	12	13	14
CO_2	418797	393943	-5.93	387828	-7.39	402503	-3.89	393943	-5.93	387362	-7.51	404281	-3.47
NO_X	4348	2616	-39.82	2442	-43.84	2617	-39.82	2469	-43.22	2329	-46.42	2531	-41.79
HC	376	105	-72.05	104	-72.21	202	-46.23	105	-72.05	104	-72.23	217	-42.28
PM	177	72	-59.50	69	-61.28	68	-61.46	70	-60.27	68	-61.75	67	-61.96
Energy [TJ]	3112675	2927950	-5.93	3001312	-3.58	3005973	-3.43	2927950	-5.93	3016012	-3.11	3021386	-2.93

Emission factors of various pollutants are different [21]. Those are subject to local conditions. Emission factors reflecting local bus operation conditions give a more precise picture on the total pollutants' emission [22]. Therefore, the emission calculated by using the model COPERT IV represents a good basis for determining the total pollutants' emission of urban buses. The results presented in the case study may represent a foundation for decision-making about vehicle choice in the bus fleet renewal process. In addition, one of the main objectives was to point out the sensitivity of the calculation to small changes in input parameters, which indicates the need for high-quality input data.

Conclusion

The influence of the chosen criteria for vehicle choice in the public procurement procedure on energy efficiency improvement and urban bus fleet renewal in Serbia has been presented in this paper. Well-conceived fleet renewal could bring to better energy efficiency, while an important emphasis should be given to the economic criterion.

The public procurement system has the leading role in motivating the fleet renewal with cleaner and energy efficient vehicles. The latter's objective is to enable an easier market access to such vehicles. The methodology for calculation of total operational lifecycle cost is used as an instrument for previously mentioned policy implementation, serving to compare and select vehicles within the procurement procedure. The input parameters for the calculation of pollutants' emission costs for vehicles in the process of procurement are based on the emission data obtained based on the unique and generally accepted methodology, generally realised and submitted by manufacturers. This allows for vehicles with different fuels to be compared and participate in the same procurement procedure under conditions that promote and emphasise sustainable transport criteria. Special attention should be allocated to an adequate selection of input elements for cost calculation, as well as to the monitoring of energy efficient vehicle operation throughout the operational lifecycle, after the procurement. It has been proven that the methodology for calculation of operational lifecycle cost is founded on sustainable procurement principles, and altogether with the model COPERT IV for pollutant emission and energy consumption estimation, represents a comprehensive and excellent basis for cost estimation, vehicle choice and fleet renewal scenario definition and assessment.

The future research in the field of fleet renewal should be focused on the development of tools for operational lifecycle cost estimation, including the other pollutants' and noise emissions.

Besides, additional future research actions should be concentrated on defining and measuring the emission factors of urban buses in different operational conditions, as well as for different fuels or propulsion systems.

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