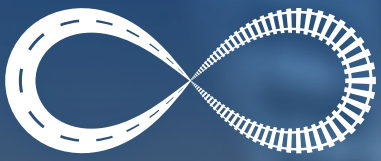

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5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

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MATHEMATICAL MODEL OF MEASUREMENT OF POSITIVE EFFECTS ON THE APPLICATION OF ELECTRICAL VEHICLES IN CITY LOGISTICS

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Abstract

According to estimates from 2010, the Canton of Sarajevo has about 465,000 inhabitants. City logistics centers are normally formed in all cities with more than 300,000 inhabitants. City logistics centers based on traffic and favorable locations on the periphery of cities or in the metropolitan area and connect the input and output streams, coordinate the flow of goods in the supply and the transportation of the urban area. This paper presents the possibility of building a city logistics center at the site of the city of Sarajevo, which we received on the basis of the method of assessment of credits offered three alternative sites. After choosing a location to build a city logistic center on the basis of mathematical methods, we calculated the effects of the electric vehicles in terms of driving energy consumption, economic viability and environmental protection between city logistics center Rajlovac-central zone of the city of Sarajevo. The paper will show the comparison of the efficiency of an electric car with respect to classical internal combustion vehicles and an analysis of the influence of classic diesel, petrol and electric motors on the environment for the planned relationship of the city of the logistics center Rajlovac – the central zone of the city of Sarajevo.

Keywords: city logistics center, an electric vehicle, power consumption, diesel and gasoline engines, CO_2

1 Introduction

The City of Sarajevo is constantly living with the problems of logistics and effects that it causes from the aspect of declining quality of life in the city. Sarajevo as the capital of Bosnia and Herzegovina has so far mainly developed around the already constructed tissue, so that the city spread radially-concentric to the traditional center. The pronounced development of residential construction on the periphery and the concentration of business activities in the central area were not promptly followed by investments in the development of the transport system, so disproportion between transport demand and the ability to meet the requirements satisfactorily. Rapid urbanization every day raises major problems in the city. The densely populated urban areas require the delivery of a larger amount of goods, generating more vehicles and increasing the crowd on the streets of the city, and this negatively reflects on living conditions, mobility and living environment. The problems of sustainability of freight transport in cities have a local and global dimension. From the aspect of the city (local dimension), transport of goods leads to a decrease in accessibility, especially in certain parts of the city and during a certain period of time (street lockout, regulation of access time, etc.) and declining quality of life in the city (aero pollution, noise, taking a significant area of the city, etc.). The big problem faced by the city of Sarajevo is the absence of a city logistic center as a logistics distribution center, which in most cases are commercial and industrial companies, which, under that name, have warehouses for

delivering products to end users in the urban environment.[1] This problem is also reflected in the degree of use of conventional petrol and diesel fuels that represent large air pollutants. It is particularly visible in the core of the city of Sarajevo where the means of transport emit smoke into the air, which contains a large number of harmful gases of CO_2 that causes the so-called greenhouse effect resulting in the creation of poor living conditions in the central zones of the city. The use of electric vehicles in the city logistics chain in the Sarajevo Canton does not necessarily mean solving the environmental problem of the city of Sarajevo but directly influences the economic viability of the companies participating in the logistics chain, etc.).

2 The possibility of building a logistic center in the city of Sarajevo

Sarajevo Canton (abbreviated KS) is one of the ten cantons of the Federation of Bosnia and Herzegovina, Bosnia and Herzegovina. The canton is located in the central part of Bosnia and Herzegovina with headquarters in Sarajevo. The canton area is 1.276,9 km^2, which makes up 4.89 % of the territory of the Federation of Bosnia and Herzegovina. According to the 2010 estimate, the canton has about 465,000 inhabitants, [2]. City logistics centers are usually formed in all cities with more than 300,000 inhabitants. They are based on traffic-favorable locations around the city or in the city area and connect incoming-outflows, coordinate the flow of goods while being supplied and taken out of the urban area, [3]. The canton consists of 9 municipalities: Centar (Sarajevo), Novi Grad (Sarajevo) Stari Grad (Sarajevo), New Sarajevo, Ilidza, Trnovo (FBiH), Ilijaš, Vogošća, Hadzici, [2]. The location of the logistics center implies the choice of the optimal place of accommodation. The location decision is one of the most important strategic decisions in every company's business. Depending on the location of the location, the narrower and broader locations are different. The choice of the wider area of the logistics center's central location is influenced by factors related to the warehouse function in the logistics system, which is the market, the type and characteristics of the goods, the transport capabilities and the availability of the professional staff. After selecting the wider area of the site, access to the location of the logistic center's narrower location is available. Factors affecting the choice of cable location of the logistics center are: size and form of terra-in, urban Plan of Areas and Development Plans, close to the public transport network, land price and construction cost, close to repair services for vehicles and equipment and mood of Citizens for a Specific Location. To make a quick decision about the most suitable location, it can serve as a benchmark. This method can be used in the pre-selection phase when a selection of locations is determined based on a limited number of criteria. For the needs of the work, three possible analyzes were possible: A-Rajlovac, B-Vogošća and C-Skenderija location and using the award method was chosen the most favorable variant for the city of Sarajevo.

2.1 Location Rajlovac

Rajlovac is away from the city's central area 16.5 km. In Rajlovac are located shopping centers and storage facilities, passenger transport buses, as well as traditional and modern food industry companies. The economic zone is 9.38 ha, where a total of 34 locations are planned in this area from the previous period and currently operates several manufacturing and service companies.

2.2 Location Vogošća

Vogošća municipality is one of the nine municipalities of Sarajevo Canton. Vogošća is located in the Bosna river basin, between Sarajevo and Visoko. The municipality of Vogošća spreads to 72 km^2, away from the center of Sarajevo about 11 km, 70 km away from the city of Zenica and 100 km from the town of Tuzla as the largest consumer centers of the country. The area has developed infrastructure, power, coal, coal, natural gas, etc. It is the optimal population and has a high degree of qualification for all workers profiles.

2.3 Location Skenderija

Skenderija is a sports-cultural-business center in Sarajevo, built in 1969, away from the center of Sarajevo, about 6 km. It is located on the left bank of Miljacka. The total area of the center is 70,000 m^2. We present a matrix on the choice of possible locations for building a city logistics center in the city of Sarajevo.In the evaluation process we took the meaning of the grade so that the grade 2 – the request is fully met, the grade 1 – the request partially fulfills and the rating 0 – the request fails.Based on the matrix on the choice of the location of the city logistics center in the city of Sarajevo we can conclude that for the construction of the modern city logistic center an optimal variant of construction in Rajlovac area for reasons:

- close to the railway line,
- motorway access,
- great flatness of soil,
- a large number of outbound and inbound routes to the Rajlovac area,
- there are no housing facilities,
- a short distance from the sales market,
- noise at a touchable level.

Table 1 Evaluation of alternative locations with the help of a score rating for the City of Sarajevo A- Rajlovac, B-Vogošća and C-Skenderija.

Factors for Alternative Location		Location Selection		
Order No.	**Requirements**	**A**	**B**	**C**
1.	Noise	2	1	0
2.	Living facilities	2	1	1
3.	Road- Highway	2	1	1
4.	Close to the sales market	1	1	1
5.	Willingness to cooperate	2	1	1
6.	Ground level	2	0	0
7.	A link to the railway track	2	2	0
Total		**13**	**7**	**4**

3 Analysis of introduction and expenditure of electric cars in the city logistic center of Sarajevo city

Today, the dominant share in road traffic belongs to vehicles powered by internal combustion engines based on fossil fuels. However, pollution reduction requirements as well as advances in the area of electric power and storage of electricity have recently increased the share of hybrid and electric vehicles in road traffic, [4]. An electric car is a car driven by an electric motor, using the energy stored in an accumulator, or other electrical storage devices.

3.1 Fuel Power Consumption Analysis of the selected city logistic center and city center of Sarajevo

The railway on the Rajlovac route as the selected location of the construction of the city logistic center and up to the central zone of the city of Sarajevo, the street Radiceva in one direction exceeds 16.50 km, data obtained based on the measurements from google maps, Figure 1. Here it is assumed that the vehicle moves constant speed, without stopping and without restart, on flat ground, dry asphalt.

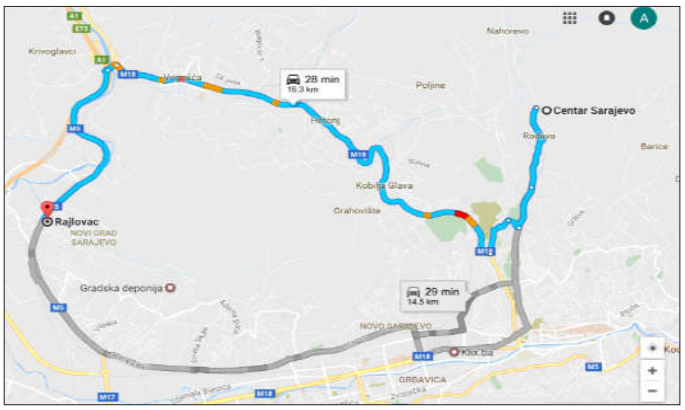

Figure 1 Rajlovac Relationship – the central area of the City of Sarajevo [5]

The travel time of the vehicle during one day for the relay given in Figure 1. is:

$$K = Kt + Kn + Kp = 16,5 + 0 + 16,5 = 33 \text{ km} \tag{1}$$

In the six-day working week, the annual fund working hours with holidays included, non-working days, are:

$$FDrgod = 365 - (52 + 8) = 305 \text{ dana} \tag{2}$$

Based on the calculated working days during one year, we can calculate and crossed kilometers per vehicle on a given route during the year:

$$Kgod = K \cdot FDrgod = 33 \text{ km/dan} \cdot 305 \text{ dana} = 10065 \text{ km} \tag{3}$$

Consumption Budget for a Conventional Vehicle

The average fuel consumption of one kilometer diesel vehicle is:

$$Pkm = \frac{6}{100} = 0,06(L) \tag{4}$$

After calculating vehicle fuel consumption per kilometer, we calculate annual fuel consumption for a given diesel vehicle:

$$Pgod = Pkm \cdot Kgod = 0,06 \cdot 10065 = 603.90(L) \tag{5}$$

The annual fuel costs for a given diesel vehicle will be:

$$\upsilon god = Pgod \cdot Cgor = 603.90(L)\ 1.71(KM/L) = 1.032,66(KM) \tag{6}$$

Budget for electric vehicles

Electricity consumption in one-kilometer electric vehicle is:

$$P(EV) = \frac{25kW}{100km} = 0,25\ (kW/km) \tag{7}$$

The total annual electricity consumption of the electric vehicle on the given route is:

$$Pgod = P(EV) \cdot Kgod = 0,25(kW/km) \cdot 10065(km) = 2516,25(kW) \tag{8}$$

The annual cost of electricity consumed by the vehicle for the given relation is:

$$\upsilon god = Pgod \cdot CEE = 2516{,}25(kW) \cdot 0{,}1(KM) = 251{,}62(KM) \tag{9}$$

The difference in the cost of using a vehicle on a diesel engine with respect to an electric vehicle at the annual level is as follows:

$$\Delta(\%) = \frac{\Delta kv - \Delta ev}{\Delta ev} \cdot 100 = 75{,}63(\%) \tag{10}$$

The realized annual savings in money for the given relation using the electric car is:

$$\Delta\upsilon god = \upsilon god(KV) - \upsilon god(EV) = 1032{,}66KM - 251{,}62KM = 781{,}04(KM) \tag{11}$$

Based on the results obtained above, it was concluded that the electric vehicle for the analyzed relationship Rajlovac to the central zone of the city of Sarajevo until returning to the city logistic center in Rajlovac is more profitable for about 75.63 %, ie reduces the operating power costs by 781,04 KM from the diesel engine vehicle on a year level.

3.2 Economical cost-effectiveness of electric vehicle use in the Rajlovac city logistics center

In modern times, road traffic is rapidly changing and adapting to new economic, ecological and energy needs. New technologies are being explored with the emphasis on the development of vehicles that are less or wholly independent of oil as a source of start-up energy. This is primarily about hybrid and electric cars. An electric car instead of an internal combustion engine has an electric motor, which brings a number of advantages, [6].

Table 2 Maintenance costs at annual level

	Electric car	Automobile with gasoline motor
Mass of the vehicle	800 kg	800 kg
Consumption at 100 km	10-15 kWh	
Electric energy	6 – 8 liters of gasoline	
The cost of energy spent per 100 km	1.00 – 2.00 KM per NT	
1.50 – 3.00 KM per VT	10,85 – 14.50 KM	
Price of annual energy spent (20000 km passed)	200 – 400 KM per NT	
300 – 600 KM per VT	2170 – 2900 KM	
Maintenance price (per year)	125 KM	750 KM
In total	325 – 725 KM	2920 – 3650 KM

From all of the above it is apparent that electric cars have more than one level of superiority to cars with internal combustion engines. Whether this is the case, we can check the economic aspect with a simple comparison. The car powered by a gasoline engine, the 800 kg weight consumes 6 to 8 l of fuel per 100 km. The price of a liter of gas Eurosuper 95, in July 2017 in FBiH was 1.81 KM. Therefore, we can calculate that the price of 100 km is between 10,86 and 14,48 KM. An electric car of similar mass and driving characteristics as the aforementioned car has a consumption of 10 to 15 kWh per 100 km. The price of kWh according to Elektroprivreda BiH in July 2017 at a lower (night) tariff is 0,10 KM, and higher (daily) 0,20 KM. Therefore, a 100 km electric car should use between 1.00 and 2.00 KM at a lower tariff, or between 1.50 and 3.00 KM at a higher tariff.If this comparison also includes the cost of maintaining the car at an annual level of over 20,000 km, we get clear economic performance indicators, as can be seen from Table 2.

3.3 Comparison of the efficiency of an electric car

Electric vehicles are much more efficient in utilizing primary energy compared to the most modern vehicles of today equipped with internal combustion engine, Figure 2. For example, an electric city car filled from renewable energy sources has 5 times the efficiency of a conventional vehicle. Their integration into the advanced (smart) power grid enables charging of vehicles in hours of lower loads of the power system as well as charging in hours with a significant share of production from renewable sources (wind power plants, photovoltaic power plants, etc.

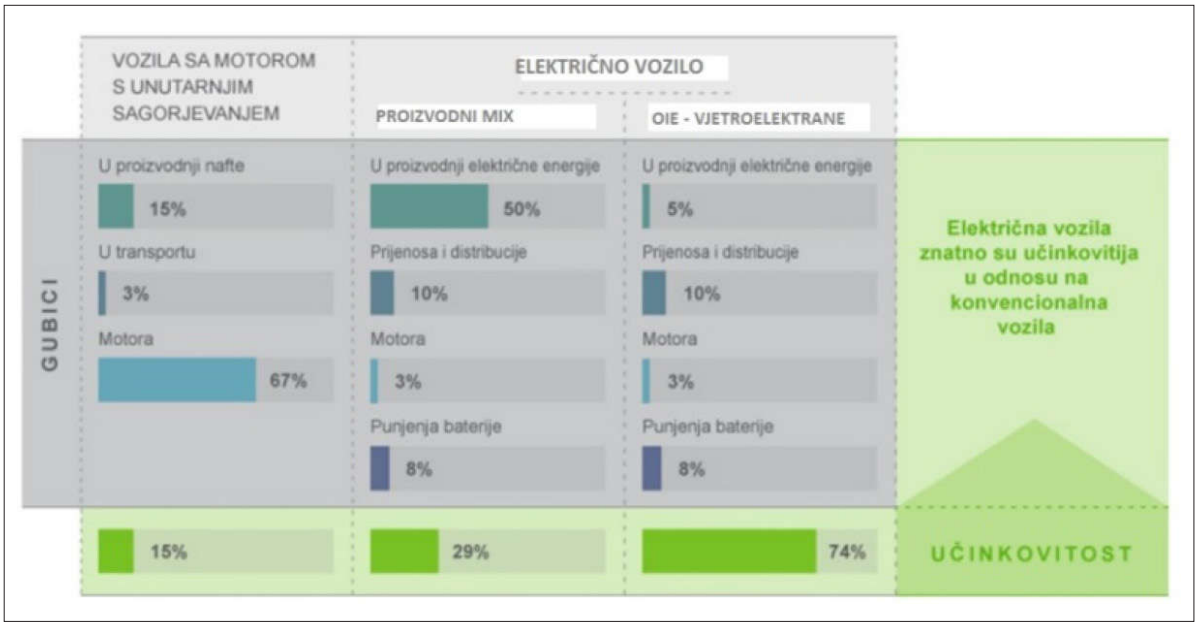

Figure 2 Comparison of efficiency of electric cars and vehicles on SUS engines [7]

3.4 Analysis of the influence of classical diesel, petrol and electric engine on the environment for the planned relationship of the city logistic center Rajlovac – central zone of the city of Sarajevo

The main disadvantages of classic diesel and gasoline engines are emission of harmful substances, noise, vibration, and consumption of non-renewable energy sources. The main advantages of the electric motor are in these areas because the electric motor has a zero emission of harmful exhaust gases and at present the only one meets the ZEV (zero emission vehicle) standards, [8]. In Europe there are more visible signs of the beginning of the Electric Revolution. The European Union envisages very clear CO_2 emission limits for cars that will have to fall below 95g / km by 2020, [9]. As an example we can take the Toyota Prius so far the lowest in the world, and they are 105gr / km. However, this value depends on the overall energy production of a single country, the more energy used in renewable sources, the value of CO_2 emitted by electric vehicles will be reduced.
The use of electric vehicles in cities will reduce the emission at local level. An example is that at the bottling plant in Croatia it is guaranteed that 100 % of the electricity produced from renewable energy sources is certified by TÜV SÜD certifying all HEP hydroelectric plants.
In the following figure, a diagram showing the comparison of the electric car, the diesel vehicle and the gasoline-powered vehicles from the point of view of the amount of CO_2 pollution and the required surface of the CO_2 absorbed forest for the observed movement relation of the vehicle.

Figure 3 Budget of pollution of individual vehicles and their impact on the environment [7]

Based on the software solution offered by HEP Zagreb on the selected link between the city logistic center Rajlovac – the central area of Sarajevo, which amounts to 10 065 km, we came to the conclusion that the use of electric vehicles in comparison with classic diesel and gas engines is much more cost effective and efficient from the aspect of fuel consumption, the amount of carbon dioxide emissions and the forest surface needed to absorb CO_2. Only in this relationship with the use of the vehicle on the benzene drive would need about 628 m^2 of wood for the carbon dioxide absorption and considering that it is a potential place for building the city logistics center, we are aware that the number of kilometers would be much greater during one year.

4 Conclusion

City logistics centers represent a link between different modes of transport through the main role both in the transport chain and in the overall transport. City logistics centers are usually formed in all cities with more than 300,000 inhabitants. They are based on traffic-friendly locations around the city or in the city itself and connect incoming-outflows, coordinate the flow of goods while delivering and departing from the urban area. It is necessary to build city logistic centers that will contribute to the optimization of the logistics network of many cities and, on this basis, to provide a more favorable, faster, safer and simpler flow of goods within cities as well as to eliminate the disparity between production and consumption or demand. In the first part of this paper, based on the location selection matrix, it was concluded that for the construction of the modern city logistic center an optimal variant of the construction of the center in Rajlovac for reasons: the vicinity of the railway line, the access to the corridor

Vc highway, the large ground level, area Rajlovac,lack of housing, a small distance from the sales market, noise at an acceptable level. The second part of the paper gives an overview of the effects of the use of electric vehicles on the connection between the city logistic center Rajlovac – the central zone of Sarajevo. Today, the dominant share in road traffic belongs to vehicles powered by internal combustion engines based on fossil fuels. However, pollution reduction requirements as well as advances in the area of electric power and storage of electricity have recently increased the share of hybrid and electric vehicles in road traffic. An electric car is a car that is powered by an electric motor, using the energy stored in an accumulator, or other electrical storage devices. Using different scientific methods, we investigated the possibility and effects of the application of electric vehicles in this relation. The study included an analysis of the power consumption of the selected city logistic center and city center of Sarajevo where, based on numerous mathematical expressions, it proved that the electric vehicle in the analyzed relation is more profitable by about 75.63 %, i.e. it reduces the operating power costs by 923.05 KM from a diesel vehicle on an annual basis. In the last part of this paper, comparisons of the efficiency of the electric car compared to the classic combustion vehicles and the analysis of the influence of the classic diesel, petrol and electric motors on the environment for the planned relationship between the city logistic center Rajlovac – central zone of Sarajevo.

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