Energy Efficiency of Tram Transport in the City of Osijek

Case Study

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Abstract *– In the city of Osijek, tram transport started long before it was introduced in many European and world cities. This paper presents the ways to increase tram traffic energy efficiency in the city of Osijek. The tram transportation system as an urban way of traffic as well as plans for further development are described. Energy efficiency indicators are presented based on electricity consumption and the number of passengers in the past decade. The tram transport system is compared with other forms of public transport in the city of Osijek. An increase in energy efficiency in the sector of urban transport is proved based on the presented data.*

Keywords *– Electricity Consumption; Energy Efficiency; Public Transport; Tram*

1. INTRODUCTION

The city of Osijek (around 115,000 inhabitants) is suitable for the organization of urban public transport; a narrower part of the city is situated along the Drava River within approximately 13 x 3 km. A long tradition of tram transportation and public transportation in Osijek is described in the paper. The paper analyzes energy efficiency in public transport, especially tram transport, and local goals of energy efficiency in public transport.

1.1. LONG TRADITION OF TRAM TRANSPORTATION

Tram was introduced in Osijek even before it was used in many European and world cities. Trams have operated in Osijek since 1884. At that time, they were pulled by horses and it was the first transportation of that kind in Croatia. Electrification of the Osijek tram line was carried out in the 1926. Today, in Croatia trams run only in the cities of Zagreb and Osijek. In some other Croatian cities trams were replaced by buses (in 1934 in Pula, in 1935 in Opatija, and in Rijeka and Dubrovnik in the late 70ies). [1]

1.2. PUBLIC TRANSPORTATION TODAY

Public transport is performed by trams and buses (a public company named GPP) and taxicabs (twenty private companies with fifty cars, two largest ones are "Osijek taxi" and "Cameo").

This paper analyzes public transport in the past 10 years with emphasis on tram transport and increasing of energy efficiency. Energy efficiency indicators of tram transport are presented.

Public transport in Osijek is organized by GPP and it encompasses 28 trams on 3 lines and 25 buses on 11 lines in the inner urban area (Osijek, Tvrđavica, Višnjevac, Podravlje) and 10 suburbs (Josipovac, Livana, Briješće, Brijest, Nemetin, Tenje, Čepin, Sarvaš i Bijelo Brdo); Fig. 1.

Basic data on GPP vehicles and data on passenger transport are shown in Table 1, and in Tables 2 and 3 and Figures 2 and 3, respectively.

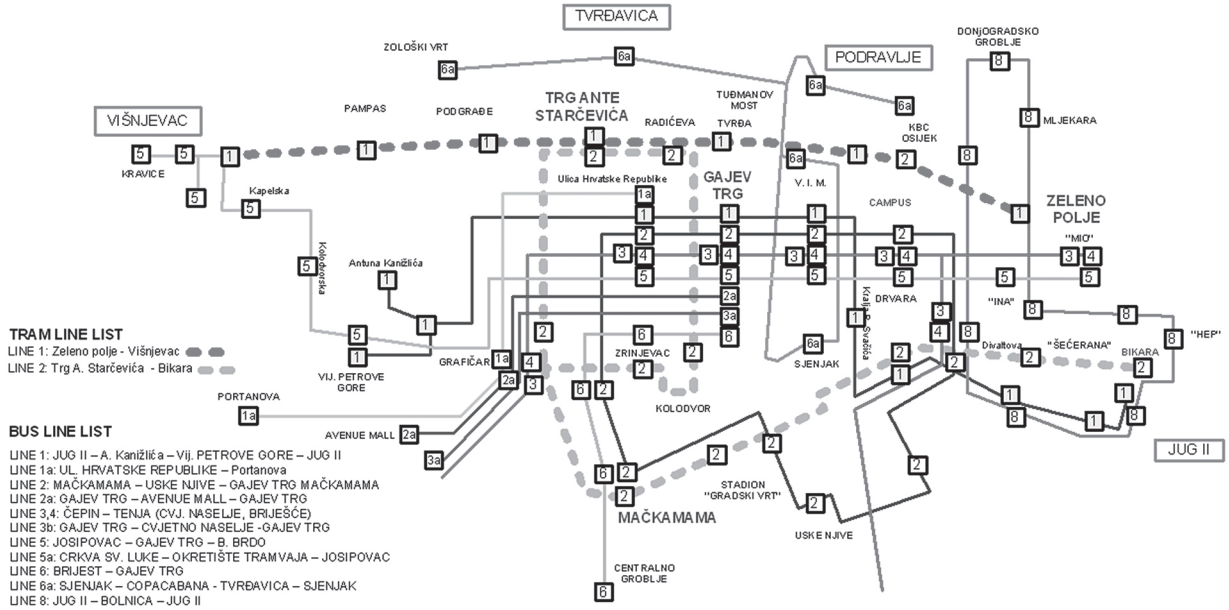

Fig. 1. Tram and bus lines in the inner Osijek area (2012)

Table 1. GPP vehicle fleet (2012)

Vehicle Model	Vehicle Type	NO of Vehicle	NO of Places for Passengers	Engine (kW)
		TRAM		
Škoda	T3RPV	17	134	4 x 40
Škoda	T3	2	164	4 x 40
Duwag	GT-6	9	192	2 x 120
Total		28	4,334	560
		BUS		
MAN	SL202	1	45 + 54	
MAN	SL 223 A74	12	36 + 61	
Probus	TBX850	2	36	
MAN	SL 228 A74	7	45 + 30	
MAN	NL 313 A21	3	32 + 60	
Total		25	2,101	

Source: [2]

Table 2. Passenger Kilometers of GPP Vehicles in Urban Transport of the City of Osijek (10^6 km)

Vehicle	2002	2004	2006	2008	2010	2012
Bus	3.50	2.71	2.72	2.94	2.40	2.59
Tram	0.77	0.73	0.81	0.95	1.26	1.30
Total	4.27	3.44	3.53	3.89	3.65	3.89

Source: [2]

Table 3. Passenger Kilometers of GPP Vehicles in Urban Transport of the City of Osijek (10^6 km)

Vehicle	2002	2004	2006	2008	2010	2012
Bus	5.45	6.19	5.82	5.86	4.14	4.47
Tram	2.99	3.06	3.16	3.30	6.08	6.43
Total	8.43	9.25	8.99	9.16	10.22	10.91

Source: [2]

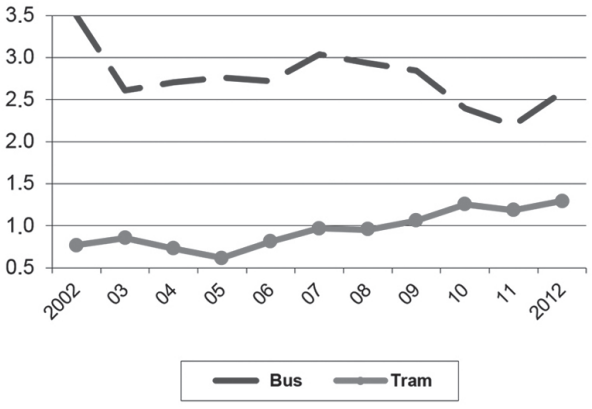

Fig. 2. Passenger kilometers of GPP vehicles in urban transport of the city of Osijek (10^6 km)

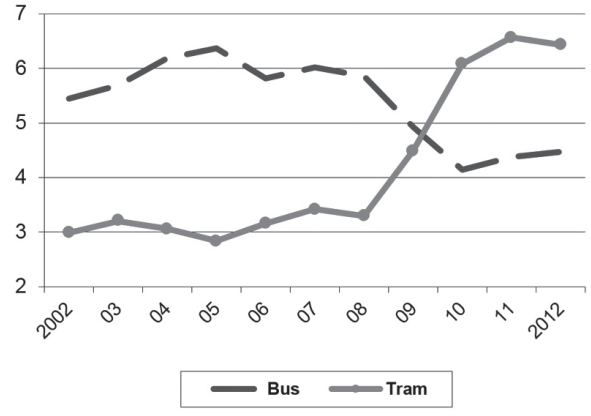

Fig. 3. Passengers transported by GPP vehicles in urban transport of the city of Osijek (10^6)

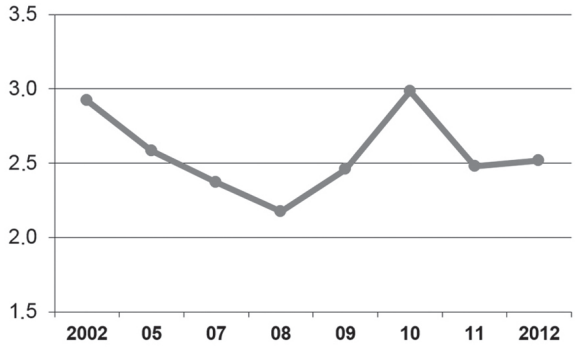

Fig. 4. Electricity used by trams in public transport of the city of Osijek (GWh)

Reconstruction of old T3 trams was the main reason for the electricity consumption decrease from 2002, as shown in Figure 4. Although electricity consumption increased from 2008 to 2010, energy efficiency indicators were also on the rise due to an increased number of passengers. Buying newer (used) vehicles was not an option because a standard tram track gauge in EU countries is 1,435 mm and in Osijek it is 1,000 mm. Reconstruction of old T3 trams was done by Krna tram factory from the Czech Republic; in addition to new design, the interior has been modernized, the electronic toll collection system, LCD and sound announcements of stations were introduced. New trams generate less noise, they are comfortable, and the control system has computer support [3]. Figure 5 presents life cycle cost analysis of motor operations over the motor lifetime [11]. More efficient motors consume less electrical energy.

Fig. 5. Life cycle cost analysis of motor operations over the motor lifetime

Tram price is just several percent of what will be spent on energy to run the tram over its lifetime. In this way, modernization of trams brought about an increase in energy efficiency. Fig. 6. shows the tram infrastructure and transport performed in 2002 and 2012, the number in brackets is the index for year 2012 (the base year 2002 = 100).

It can be observed that all indicators are on the rise (indices 118-215), with the exception of electrical energy consumption (index 86.4).

Tram transport is more efficient than bus transport. Passenger per kilometer index in the city's public transport indicates that buses carry two passengers per one kilometer (in 2002 = 1.56, in 2012 = 1.73), while trams transport five passengers per kilometer (in 2002 = 3.87; 2012 = 4.97); Fig. 7.

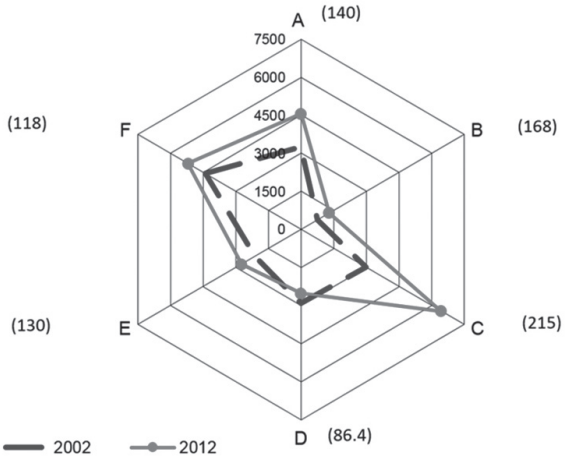

Fig. 6. Tram infrastructure and transport passengers in Osijek in 2002 and 2012

Legend
A = the number of passenger seats;
B = vehicle km travelled (106)
C = the number of passengers (106);
D = electricity used to drive (MWh);
E = length of tram lines (00 m);
F = power of traction motors (kW).

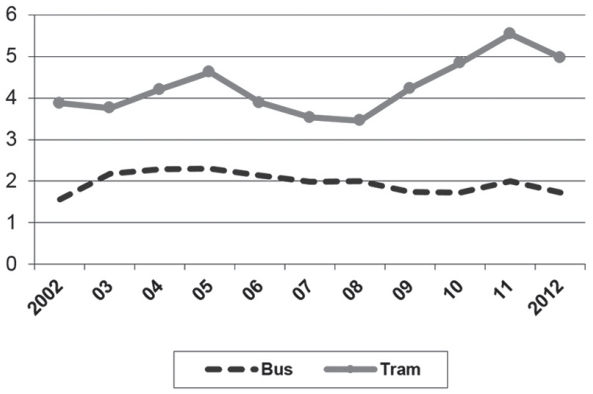

Fig. 7. Passengers transported in public transport of the city of Osijek per kilometer (passenger/km)

2. ENERGY EFFICIENCY IN PUBLIC TRANSPORT

In terms of energy intensity, the Republic of Croatia is significantly below the EU average [4], [5]; in 2006, with a €1000 GDP Croatia consumed 295 kg of oil equivalent in comparison with EU 27 =131, Germany=98.9, in a significant part of what contributes to the irrational organized transport of people and goods. [6]

National documents provided for an increase in energy efficiency. [9] [10]

A. LOCAL GOALS OF ENERGY EFFICIENCY IN PUBLIC TRANSPORT

The energy efficiency program in the consumption of the Osijek-Baranja county (OBC) in the period 2012-2014 with reference to the year 2016 [7], [8], provides

for the transport sector four groups of measures with multiple objectives for each group:

a) Vehicles owned by local and regional government (4 tasks),

b) Public passenger transport (5),

c) Personal and commercial vehicles for passenger transport (4),

d) Freight transport (2).

In the sector of public passenger transport, five measures were envisaged through new norms; better organization and modernization projects should contribute to better public transport and reduce the usage of energy and CO2 emissions. [1]. These are:

1. Introduction of green public procurement for public transport vehicles.
2. Changing the system of payment of transportation to employees.
3. New timetable in urban/suburban passenger transport.
4. Introduction of public transport in other OBC cities.
5. Introduction of a network of bikes for rent.

B. ENERGY EFFICIENCY OF THE CITY OF OSIJEK TRAM TRANSPORT

The overall energy efficiency of tram traffic is increasing. As tram traffic electricity consumption declined at the rate of 1.5% per year and the number of passengers grew by 8% annually, passengers transported per kWh electricity indicator grew by 9.6%, as shown in Figure 8.

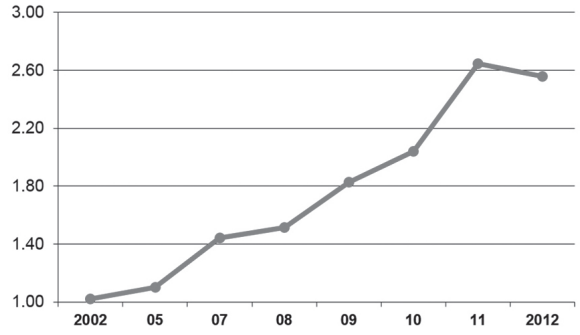

Fig. 8. Passengers transported in the city of Osijek traffic by tram per electricity (passenger/kWh)

The results of further analysis of most frequently used public transportation in the Osijek area are shown in Fig. 9, which presents better relations in relation to increased energy efficiency in tram traffic for the period 2002-2012;

- Passenger per km; index = 128;
- Transport of passengers per kWh of used electricity; index= 249;
- Passenger per km of tram lines, index = 166;
- Number of passengers per kW of engine power, index = 182;
- Transport of passengers per employee in GPP, index = 239.

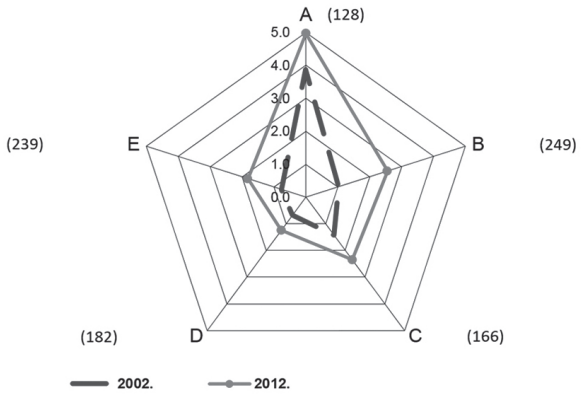

Fig. 9. Dynamic analysis of energy efficiency of tram traffic in Osijek in the period 2002-2012

Legend

A = passengers per km travelled,

B = passengers per kWh of used electricity,

C = passengers per km of tram lines,

D = passengers per kW of engine power,

E = passengers per employee in GPP.

It should be noted that the economic crisis contributed to such favorable developments (energy more efficient urban transport trams) because unemployment increased in Croatia (Osijek) and caused the population to use cars much less and orient increasingly towards public transport.

3. CONCLUSION

National development documents of the Republic of Croatia have predicted that energy efficiency would increase in final energy consumption; i.e. the building sector, traffic and public lighting.

County strategic development documents take into account energy efficiency targets of the Republic of Croatia (EU) and provide the analysis and planned measures in documents referring to counties/big cities. Osijek-Baranja County has developed measures to increase energy efficiency by the year 2016, including the transport sector.

Public transport in the city of Osijek is performed by trams and buses (a public company GPP) and taxicabs (privately owned companies with fifty vehicles).

This paper has identified an increase in energy efficiency tram traffic as most frequently used public transportation in the area of Osijek in the period 2002-2012. Performance indicators are as follows:

- Passenger per km; index = 128;
- Transport of passengers per kWh of used electricity; index= 249;
- Passenger per km of tram lines, index = 166;

- Number of passengers per kW of engine power, index = 182;
- Transport of passengers per employee, index = 239.

Modernization of T3 trams was the main reason for the electricity consumption decrease from 2010 and an increase in tram transport energy efficiency in the city of Osijek.

4. REFERENCES

[1] H. Glavaš, M. Ivanović, D. Blažević, Program of effective final energy consumption in the area of Eastern Croatia, 1st International Scientific Conference "Economy of Eastern Croatia - yesterday, today and tomorrow", S. Singer, A. Mašek Tonković, D. Barković, M. Gajos (Eds.), Osijek, 20 May 2012, pp. 54-64.

[2] GPP Osijek – Data on operations.

[3] H. Glavaš, M. Ivanović, T. Keser, Energy efficiency of road traffic, Ž. Šakić (Ed.), Korema, Ljubljana – Koper, 2012, pp. 54-64.

[4] H. Glavaš, D. Blažević, M. Ivanović, Quality and energy efficiency of public lighting in the area of Osijek-Baranja County, Technical Gazette, Vol. 19, No. 3, 2012, pp. 549-556.

[5] Milan Ivanović, Science and Regional Energy - research on energy development and utilization of energy in Slavonia, ETF Osijek, Osijek, Croatia, 2006.

[6] M. Ivanović, D. Blažević, H. Glavaš, The structure of electricity consumption and its utilisation efficiency in European transition countries, International Journal of Electrical and Computer Engineering Systems, Vol. 1, No. 2, 2010, pp. 112-126.

[7] M. Ivanović, H. Glavaš, D. Blažević, Program učinkovitog korištenja energije u neposrednoj potrošnji na području Osječko-baranjske županije za razdoblje 2012.-2014. s osvrtom na 2016. godinu - studija, ETF Osijek, Osijek, 2011.

[8] M. Ivanović, H. Glavaš, D. Blažević, Plan učinkovitog korištenja energije u neposrednoj potrošnji na području Osječko-baranjske županije za 2012. godinu, ETF Osijek, Osijek, 2011.

[9] Ministry of Economy, Ministry of Construction and Physical Planning, Second National Energy Efficiency Action Plan for the Period from 2011 to 2013, Zagreb, 2012.

[10] Government of the Republic of Croatia, Energy Strategy of the Republic Croatia, NN 130/09.

[11] F. Steyn, Motors and drives for improving energy efficiency, Energy Effciency Convention, SAEEC 2011, Johannesburg, South Africa, 16-17 Nov., 2011, pp. 1-7.